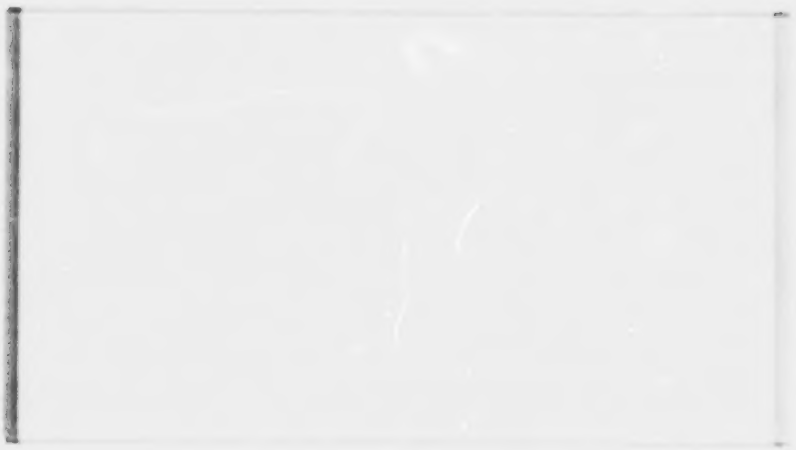
Ontario Hydro



RESEARCH DIVISION

91602
new 82-10

ontario hydro
research division

DAM SAFETY PROGRAM
TECHNICAL HISTORY
CONCRETE AND MATERIALS SUMMARY

Report No 86-255-K

E. McColm - Engineer
P.K. Mukherjee - Sr Engineer
Concrete Technology Section
Civil Research Department

ABSTRACT

This report summarizes information on the properties of concrete and related materials used in various hydraulic structures on the St. Lawrence and Madawaska River systems. The information contained within this report is extracted from the records kept with the Research Division and Central Records.

job	file	date	report no.
42-135-575	842.19	December 17, 1986	86-255-K

TABLE OF CONTENTS

		Page
1.	INTRODUCTION	1
2.	GENERAL REVIEW	1
3.	MATERIALS SUMMARY	2

APPENDICES

A	R.H. Saunders GS	10
B	Iroquois Dam	25
C	Arnprior GS	31
D	Stewartville GS	42
E	Calabogie GS	52
F	Barrett Chute GS	57
G	Mountain Chute GS	70
H	Kamaniskeg Lake Dam	80
I	Bark Lake Dam	87
J	Barrett Chute GS Extension, Stewartville GS Extension and Calabogie GS Remedial Work	93

DISTRIBUTION last page

ontario hydro
research division

To Mr. J.V. Doyle
Manager, Civil Works
Thermal & Hydraulic Generation

Attn: Mr. O. Bernaus

DAM SAFETY PROGRAM
TECHNICAL HISTORY - CONCRETE AND MATERIALS SUMMARY

1. INTRODUCTION

The purpose of the Dam Safety Program is to meet Ontario Hydro's responsibility in the area of public and employee safety relating to the operation of dams and reliable hydraulic energy production[1]. One of the aspects of this program is the documentation of the technical history for each hydraulic structure using all relevant information on the design, construction and operation. As a part of this Technical History documentation, a report[2] was issued providing a bibliographic listing of reports and files stored with the Research Division and Central Records. The information related to the quality of concrete in the above documents has been summarized in this report for selected hydraulic structures on the St. Lawrence and Madawaska River systems. The appendices contain data on materials used in each structure.

2. GENERAL REVIEW

The pertinent reports and files stored with the Research Division and Central Records deal almost entirely with the testing of concrete and its components, including the quality control of concreting operations and the inspection and investigation of the structures. All reports referred to are Research Reports issued by the Research Division, unless otherwise noted, and can be obtained from the Research Division, General Office at KR107. Requests for the files stored with Central Records should be made to Central Records at KD170. All other files including History Files, Concrete Laboratory Files and Project Files are for the internal use of the Concrete Technology Section.

---

1. "Ontario Hydro, Dam Safety Program" Civil Works Department, Thermal & Hydraulic Generation Division, October 1985.

2. Ontario Hydro Research Report No: 86-174-K, "Dam Safety Program - Bibliography".

The actual materials and proportions used during construction may vary from those suggested or proposed in the reports and memos. Many reports were issued on the testing and analysis of the materials (particularly for aggregate surveys) that were eventually not used. The concrete inspectors' reports, the results of tests conducted on site during construction and the tests on the structure itself provide a more realistic indication of the actual materials used and their properties.

The appendices contain summaries of the material properties for each station under the following headings: Cement, Fine Aggregate, Coarse Aggregate, Admixtures, Fly Ash, Water, Concrete, Miscellaneous, Post-Construction Investigations. Each heading has been referenced to indicate where the information was obtained from. Tables summarizing the test results and in some instances containing the physical properties of reference samples have been included. An attempt has been made to use a data base as large as possible or practical when reporting the test results. On some occasions only one or two reference samples could be located. In other instances there was an overwhelming amount of data with no summary present. In these cases a partial summary of the data was prepared. The investigations and testing performed after construction are usually summarized in research reports.

It should be noted that the testing and inspection were based on the standards and codes used at the time of construction. These may differ from present day standards. Some of the testing methods have been revised or changed since these structures were built. The values listed in the appendices or used in this report were left in imperial units.

The designations "mass" and "face" are used in this report to identify the two main classes of concrete. The mass concrete generally had a lower strength and was used in the interior of gravity dams. The face concrete was used on exposed surfaces where some resistance and structural strength were required. On some projects, these two classes were also referred to by various other names such as core, structural and interior, exterior.

For some structures there was very little, if any, information available on the construction or subsequent investigations (eg, Iroquois Dam, Calabogie GS).

3. MATERIALS SUMMARY

The following sections give a general discussion on the properties of the concrete and related materials for each structure. Detailed information is attached in Appendix A to J.

3.1 R.H. Saunders GS

This station was constructed on the St. Lawrence River between 1954 and 1959. The St. Lawrence Power Project which included the generating station and all control structures was a joint venture of Ontario Hydro and the Power

Authority of the State of New York. The generating station on the Canadian side of the river was named R.H. Saunders GS. Appendix A includes details of the properties of the concrete and related materials.

Type 10 Normal Portland Cement was supplied by Canada Cement Company, Belleville mill. In 1956 there were considerable problems encountered with the supply of cement and high levels of sulphur trioxide. Modifications had to be made to the manufacturing process as well as the acceptance criteria in order to supply the project. By the end of the year both the supply and the quality had improved. Fly ash was used as a 20 to 25% replacement for the cement in the ice sluice girders and scrollcase area. Protex was selected as the air-entraining admixture after laboratory and field tests were performed on 14 products.

An extensive aggregate search was conducted in the area around the project and extended as far as Quebec and New York state. The fine aggregate deposits in the vicinity of the site were found to be unsuitable or required excessive amounts of work. It was finally decided to manufacture the sand from the Cornwall Centre quarry (Pitt's quarry) rock. This was the first time Ontario Hydro had used manufactured sand on a large project. The sand was sometimes blended with natural sand. This limestone quarry was also used to produce the three sizes of coarse aggregate (3" maximum).

The two basic classes of concrete were mass and face. The mass concrete had a design strength of 2500 psi and generally contained from 350 to 440 lb/yd^3 of cement. The face concrete had a design strength of 3000 psi and contained from 440 to 570 lb/yd^3 of cement. The cement content and the mix proportions were altered as the performance of the concrete was established, and for the various placing conditions. There were a large number of concrete tests performed during construction. Appendix A contains the results of a portion of these tests.

Concrete cylinders were cast on the job for testing by the Civil Research Laboratory at various periods up to 100 years. These concrete test cylinders achieved their maximum strength after about five years. Further test data from this program have not yet been evaluated. Since the station has been in operation, investigations have been conducted into the apparent deformation of the throat rings. This was thought to be caused by external forces on the dam or from the expansion of the concrete due to the reactivity of the aggregate and cement. From laboratory tests on these materials and the monitoring of the structure, there appears to be no expansive tendencies of this concrete as of 1982 (Appendix A, Section 9).

3.2 Iroquois Dam

This control dam was constructed 28 miles upstream and at approximately the same time as R.H. Saunders GS. The only information on the construction of Iroquois Dam is two concrete control reports for April and August 1956 issued by Uhl, Hall and Rich Engineers. This firm was involved in the construction of the American portion of the St. Lawrence Power Project. The details of these reports are contained in Appendix B.

Two American companies supplied ASTM Type II Portland Cement (equivalent to CSA Type 20 Moderate Portland Cement). The air-entraining admixture was Protex. A blend of natural and manufactured sand was used for the fine aggregate. The quarry at the Daggett lease provided crushed dolomite rock in four sizes (6" maximum) for the coarse aggregate.

The concrete was classed as face and mass. The various mixes were further broken down by the maximum size of aggregate. The face concrete contained about 400 lb/yd^3 of cement with a water/cement ratio of 0.45. The mass concrete contained about 300 lb/yd^3 of cement and had a water/cement ratio of 0.52.

It should be noted that this summary, particularly the values, was compiled from a very limited source of information.

3.3 Arnprior GS

Arnprior GS was constructed on the Madawaska River from 1973 to 1976 by Acres Consulting Services Ltd. There is not a great deal of information available on this station since the construction and inspection were contracted out. The aggregate survey and some of the testing of the concreting materials (fly ash, cement) was conducted by the Civil Research Department. At the completion of this project Acres published a report on the concrete quality control. This report contains a summary of the properties of the materials and of all testing conducted during construction. Details of the material properties are contained in Appendix C.

Type 10 Normal Portland Cement was supplied by Lake Ontario Cement Company, Picton mill. Fly ash from the Detroit Edison Company's Trenton Channel power plant was used as a 20 to 30% replacement for the cement in some mixes. The carbon content of the fly ash fluctuated widely causing problems in maintaining the proper air content in the concrete. In 1973 Pozzolith 80 was used as the water-reducing admixture and MBVR (Master Builders Vinsol Resin) as the air-entraining admixture. From 1974 to 1976 the water-reducing admixture was changed to MBL (Master Builders Lignin) and the air-entraining admixture to Darex. Two sizes of coarse aggregate (1-1/2" max) were obtained from the Braeside quarry at Braeside. This material was washed before being delivered. The parent rock in this quarry consisted of microcrystalline limestone. The Riddell pit at Galetta supplied the fine aggregate.

The five main classes of concrete had design strengths ranging from 3000 psi to 5500 psi. These classes could be broken down into three main categories, core, face and structural. Information on post-construction investigations could not be located.

3.4 Stewartville GS

The initial construction of this station took place between 1946 and 1950. An account of this work was reported by the Civil Research Department. The properties of the concrete and related materials for this station are contained in Appendix D.

Canada Cement Company, Hull mill, supplied Type 10 Normal Portland cement. Fly ash was not used and air-entraining admixtures were used for trial testing on one pour only. McLaren's pit, a natural sand and gravel deposit, supplied all the aggregates for this project. The coarse aggregate was screened into 3 sizes with the rock over 3" crushed.

Face concrete with a design strength of 3000 psi and mass concrete with a design strength of 1750 psi were used. The face concrete generally contained about 462 lb/yd^3 of cement and the mass concrete 332 lb/yd^3. The proportions of the coarse aggregate size fractions were sometimes altered to take advantage of the material stockpiled at the mixing plant. During the concreting operations the mixing plant never reached the estimated rate of production. Because of this, modifications had to be made to the method of concrete placing on some pours.

During construction 317 instruments were installed, mainly in blocks 11 and 12 of the main dam. These instruments were intended to be used to measure internal temperatures, stresses and strains. Large cracks that appeared during construction were investigated using the Soniscope (ultrasonic testing device).

There have been many investigations and tests conducted on this dam since construction. The cylinders used in the long-term concrete tests gradually increased in strength over the first 15 years. Further test data have not yet been evaluated for this program. Between 1951 to 1954 the uplift pressure on the main dam was monitored annually. Also during this period concrete cores were taken from the main dam and the Soniscope tests conducted. These investigations and testing indicated that the concrete appeared sound and that there was no sign of internal cracking in the dam. In 1983 and 1984 two zones of major leakage under the main dam were sealed using hot asphalt and conventional cement grouts.

Stewartville GS was extended by two units in 1967 to 1969. This work coincided with the modifications to other stations on the Madawaska River and is reported in Section 3.10 and Appendix J.

3.5 Calabogie GS

Calabogie GS was placed in service in 1917 and acquired by Ontario Hydro in 1929. Information on the original construction could not be located. Remedial work was performed on this station in 1937 and from 1967 to 1969. A summary of the materials used in the 1960's is contained in Section 3.10 and Appendix J. Concrete cores were obtained and the Soniscope tests conducted on this dam in the mid-1960's (Appendix E). During the drilling investigation it was noted that the coarse aggregate became smaller in size and less abundant with depth.

3.6 Barrett Chute GS

This structure was constructed on the Madawaska River from 1941 to 1942. Most of the information on the original work on Barrett Chute GS is contained in a

report prepared by the Civil Research Department at the time of construction. The properties of the concrete and related materials are detailed in Appendix F.

The cement, Type 10 Normal Portland, was supplied alternately by St. Marys Cement Company, St Marys mill and Canada Cement Company, Hull, Quebec, mill. Modified Type 10 cement was also ordered from Canada Cement Company, but the actual date of delivery is not known. This cement was modified to try and meet the specifications for Type 20 Moderate Portland cement. Fly ash and air-entraining admixture were not used in this concrete. Pozzolith water reducer was only used in the last 100 yd^3 of concrete placed in the closure plugs. The Legree pit, a natural sand deposit, provided the fine aggregate. As the job progressed, a seam of fine sand was encountered which had to be washed in order to meet the specification. The coarse aggregate, red granite and green gneisses, was taken from the canal excavation. Only one grading of crushed rock was produced, having a maximum size of 3". When the concrete was to be placed around reinforcing steel, an additional 2" screen was used to obtain a finer grading.

The two classes of concrete were face and mass. The face concrete was subdivided into structural and waterline with a design strength of 3000 psi and contained 482 and 525 lb/yd^3 of cement, respectively. The mass concrete had no strength specified, but 2000 psi was assumed. The cement content of the mass concrete was 350 lb/yd^3. The proportions of the mixes were altered as the performance of the concrete was established and for various placing conditions. During construction, the headworks structure was damaged by a major fire in the formwork.

Instruments were placed in Block 16 of the main dam during construction. These were used to measure the changes in stress, strain and internal temperature. Readings two years after construction did not indicate any build up of stress or movement of the dam. In addition, thermocouples were also placed in the concrete to measure the internal temperatures generated due to the heat of hydration.

Since this dam has been in operation, a number of investigations have been conducted to determine the extent of cracking and the quality of the concrete. The long-term concrete cylinders showed a continual increase in compressive strength over the 15 year period of this test. The Soniscope investigations conducted in 1947 concluded that there was no evidence of internal cracks parallel to the axis of the dam. The concrete cores taken from the main dam in 1945 and tested in 1950 and 1951 indicated that the concrete was of good quality and fairly uniform.

An additional two units were added to this station in 1967 to 1969. A summary of the materials used in this work is given in Section 3.10 and Appendix J.

3.7 Mountain Chute GS

Mountain Chute GS is located on the Madawaska River and was constructed between 1965 and 1967. The concrete for this project was produced on site

until February 1967 after which it was purchased from Smith Construction's Burnstown plant. The properties of the materials used in the concrete produced by Smith Construction are described in Section 3.10 and Appendix J. The properties of the materials and of the concrete produced on site are contained in Appendix G.

A fly ash/cement combination was used in most of the concrete produced on this job. Type 10 Normal Portland Cement was supplied by Canada Cement Company, Belleville mill. The majority of the fly ash was purchased from Detroit Edison Company, Trenton Channel plant. Ontario Hydro's R.L. Hearn GS also supplied some fly ash. The fly ash from R.L. Hearn GS generally had a high carbon content which caused problems in maintaining the proper air in the concrete. Daravair was used for air-entraining and Daramix was the water-reducing admixture. The fine aggregate came from a sand and gravel pit identified as Location #4. This sand generally had to be blended to meet the specifications. The coarse aggregate was supplied from a quarry near the project identified as Site No. 1A. Four sizes of crushed rock were produced with a maximum size of 6". The parent rock in this area is biotite and biotite-amphibole gneiss and calcitic marble. This rock had to be washed to remove the fines. In winter when it was too cold to wash the coarse aggregate, additional cement had to be added to the mixes.

Mass and face concrete were used with about 11 different mixes. The design strength of the mass concrete varied between 1750 psi and 3000 psi and the face concrete between 2500 psi and 3000 psi. The mix proportions were altered for various placing conditions and for the quality of the aggregates. The results of the concrete cylinder tests reported in Appendix G are for a portion of the data and are representative of the tests conducted on site.

During the first few months of this project, a great deal of difficulty was encountered in obtaining the proper consolidation of the concrete. It was suggested that this could have been caused by a number of factors, including inexperienced placing crews, the use of a bulldozer to spread concrete, and the vibrators breaking down. An extensive drilling and water testing program was implemented on blocks in which the consolidation of the concrete was thought to be poor. On completion of this program, a 4-foot thick remedial wall was built on the upstream face of the questionable sections.

Concrete cylinders were cast during construction for testing up to 100 years. The test specimens reached their maximum strength after about one year. Further analysis of the data from this program has not yet been conducted.

3.8 Kamaniskeg Lake Dam

This small storage dam was constructed on the Madawaska River in 1956-1957, below Kamaniskeg Lake. The dam was originally estimated to require about 2450 yd^3 of concrete. The only information located on this structure was three files stored with Central Records. Appendix H contains details from these files on the concrete and related materials.

St. Marys Cement Company Limited supplied Type 10 Normal Portland Cement from their St Mary's mill. Fly ash was not used and admixtures were used for trial testing only. The fine aggregate was obtained from a natural sand and gravel deposit on Paugh Lake Road. This was the same source of sand used for the construction of Bark Lake Dam. Most of the coarse aggregate was obtained from the stockpile of crushed rock remaining at Bark Lake Dam. The rock in this stockpile was in the 3/4" to 1-1/2" size range. Additional stone was supplied from the gravel screened from the Paugh Lake Road pit. This stone was not of the best quality and had been previously rejected for use in the construction of Bark Lake Dam. The Paugh Lake stone was mixed with the Bark Lake crushed rock. Initially, this did not always occur.

Only one concrete mix was used, having a design strength of 3000 psi and containing 570 lb/yd^3 of cement. In one case low compressive strengths were obtained from tests on a set of concrete cylinders. This was thought to be caused by an excessive amount of the Paugh Lake gravel in the mix.

3.9 Bark Lake Dam

Bark Lake Dam is located on the Madawaska River just downstream from Bark Lake. It was built between 1941 and 1942 by the Dominion Construction Company. A report prepared by the Civil Research Department contains a detailed account of the materials used and the construction. Appendix I provides a summary of the properties of the concrete and related materials used in this dam.

Modified Type 10 Normal Portland Cement was supplied by Canada Cement Company, Hull mill. This was the same cement as used on the Barrett Chute GS project. The Type 10 cement was modified to try and meet the requirements for Type 20 Moderate Portland Cement. Fly ash and admixtures were not used with this concrete. The sand and gravel pit on Paugh Lake Road supplied the fine aggregate. Crushed rock in the 3/4" to 1 - 1/2" size range was obtained from a quarry near the project. The concrete mix contained approximately 570 lb/yd^3 of cement and had a design strength of 3000 psi.

On an inspection trip 10 years after construction, the concrete appeared to be in good condition except for some minor cracks.

3.10 Barrett Chute GS Extension, Stewartville GS Extension and Calabogie GS Remedial Work

Between 1966 and 1969 extensions were added to Barrett Chute GS and Stewartville GS and remedial work performed on Calabogie GS. The concrete for this work as well as that used to complete Mountain Chute GS from February 1967 onwards was supplied by Smith Construction Company from their Burnstown mixing plant. The details of the concrete and related materials are contained in Appendix J.

Special Low Heat Portland Cement was chosen as an alternative to a cement/fly ash combination. This cement was supplied by Canada Cement Company, Hull Quebec mill. Hydro Quebec's specification was adopted because this was the

first time Ontario Hydro had used this cement. Initially, there were problems in meeting the strict requirements and the specification had to be relaxed and some cement blended. MBVR (Master Builders Vinsol Resin) was used as the air-entraining admixture and Pozzolith 4H was used as the water reducer.

McLaren's pit supplied the sand. This was the same source of fine aggregate as used in the original construction of Stewartville GS. The coarse aggregate was obtained mainly from the Jamieson's pit with some screened stone from the McLaren's pit also being used. The gravel was screened into three sizes with the maximum being 3". This rock consisted mainly of aplite, aplitic and biotite gneisses with some dolomitic and calcitic marbles.

The four main classes of concrete were mass, face, miscellaneous and waterline. Other classes were used for applications such as floor finishing. The mass concrete had a design strength of 2500 psi and the face and miscellaneous mixes had a design strength of 3000 psi. Appendix J contains the results of concrete tests performed on specimens from Calabogie GS and Barrett Chute GS.

Concrete test cylinders were prepared during construction for testing at periods of up to 100 years. The cylinders to date have exhibited a general increase in compressive strength. A complete analysis of the results from this program has not yet been completed.

Approved by:

T.W. Klym
Manager
Civil Research Dept

Prepared by:

E.J. McColm
Engineer
Concrete Technology Section

Submitted by:

P.K. Mukherjee
Sr. Engineer
Concrete Technology Section

Reviewed by:

G.S. Kellay
Supervising Engineer
Concrete Technology Section

EJM/lct/mao

APPENDIX A

R.H. SAUNDERS GS - MATERIALS SUMMARY

APPENDIX A

R.H. SAUNDERS GS - MATERIALS SUMMARY

Constructed 1955-1959

River System-St. Lawrence

There is a large amount of information on this project stored with the Civil Research Department. The general files and the concrete inspectors' daily reports are located with Central Records. A number of research reports were issued in connection with the aggregate survey and testing associated with this station.

1.0 Cement

1.1 Source - Canada Cement Company, Belleville mill.

1.2 Type - Type 10 Normal Portland Cement.

1.3 Physical Properties - Table A1 contains the physical and chemical properties of three representative samples of the cement tested during construction. All these samples met the specified requirements for Type 10 cement. There were, however, problems with the sulphur trioxide content of some of the cement used on this project.

1.4 Comments - Between December 1955 and July 1956, the sulphur trioxide content of the cement was above the specified limits. This was caused by a problem with the gypsum feed at the mill, which was corrected by August 1956.

From the end of August (20/08/56) until November, there was a shortage in the supply of cement. This resulted in the cement having to be released on the basis of three-day tests rather than the specified seven-day tests. On 27/09/56,5200 barrels were released with no tests being performed. By the end of the year the quality and supply had improved. Another instance of high sulphur trioxide content occurred in September 1957. This only lasted for a short period.

Other than the problems mentioned above, the cement was of good quality and met the specification.

1.5 Reference - Report 56-319 Cement inspection reports.
56-388
56-466
57-8
Concrete Laboratory File 452.2.1. Chemical analysis.
Concrete Laboratory - C.L. Cards. Physical tests on cement.

2. Fine Aggregate

2.1 Source - Cornwall Centre quarry (Pitts quarry).
- Manufactured sand.

2.2 Physical Properties - Table A2 contains typical examples of the gradings of sand used on this project. These results were obtained from tests conducted by the Civil Research Department.

2.3 Preparation - Rock (limestone) was quarried and crushed into sand. Fine natural sand was sometimes blended with the manufactured sand.

2.4 Comments - An extensive search was conducted for a source of fine aggregate. The deposits near the project were found to be unsuitable or required excessive amounts of work. It was finally decided to manufacture sand from the local limestone.

2.5 Reference - Central Records File 14-7-245-6 Summary of aggregate tests.
Reports - Numerous reports were issued dealing with the aggregate search and testing.
Laboratory File 51.2.4

3. Coarse Aggregate

3.1 Source - Cornwall Centre quarry (Pitts quarry)
- Limestone

3.2 Physical Properties - Table A3 contains the results of grading tests performed on coarse aggregate sampled from the batching plant. These results were obtained from tests conducted by the Civil Research Department.

3.3 Preparation - The rock (limestone) was quarried and crushed into three sizes of coarse aggregate (3/4", 1-1/2", 3").

3.4 Comments - The initial mix designs specified structural concrete and concrete to be placed around reinforcing steel to be made with a maximum of 1-1/2" aggregate. Mass concrete was to be made with a maximum 3" crushed rock. In practice, 3" aggregate was used with some of the structural (face) mixes.

3.5 Reference - Central Records File 14-7-245-6 Summary of aggregate tests.

Reports - Numerous reports were issued dealing with the aggregate search and testing.

Laboratory File 51.2.4

4. Admixtures

4.1 Type - Protex (air-entraining admixture)
Supplied by Autoline Lubricants Co,
1331 West Evans Ave,
Denver 9, Colorado, USA

4.2 Comments - Initially, 14 different admixtures for air entrainment were tested in the Concrete Laboratory. From the results of these tests it was concluded that there was no significant difference between most of the products. Three of the admixtures (Vinsol NVX, Protex (Double Strength), Darex (Double Strength)) were tested on the job in about 10,000 cu yd of concrete each. Protex was chosen from these and used in the majority of concrete.

4.4 Reference - Report 56-37
Laboratory File 51.6.10

5. Fly Ash

5.1 Source - Detroit Edison Company.

5.2 Physical Properties - The physical properties of the fly ash are given in Table A4. In the compressive strength test, the "test mix" had 20% of the cement replaced with fly ash. The control specimen did not contain fly ash. Each set of data is the average of tests on three specimens.

5.3 Comments - Fly ash was used as a 20-25% replacement for the cement in the ice sluice girders and the scollcase area. In tests performed on the fly ash, the 20% fly ash mix obtained a compressive strength of 95% of the control mix after 28 days (Table 4).

5.4 Reference - Report MM57-1 MM57-21
MM57-3 MM57-25
MM57-4 MM58-11

6. Water - Information not available.

7. Concrete

7.1 Classes - The basic classes of concrete were structural (face) (3000 psi) and mass (2500 psi). Table A5 contains the specified design criteria for each of these classes.

7.2 Mixes - The mix proportions were changed as the performance of the concrete was established on the job. The mixes were also altered for various placing conditions and types of aggregate. The mass concrete generally contained a maximum 3" aggregate unless it was being placed around reinforcing steel where a maximum 1-1/2" aggregate was used. Structural (face) concrete generally contained a maximum 1-1/2" material. Table A6 gives some of the typical mix proportions.

7.3 Strength Results - Table A7 contains a portion of the results of the concrete tests performed during construction. The results are broken down by the cement content of the mixes. The mass concrete generally contained between 350 to 438 lb/yd^3 of cement and the structural (face) concrete contained from 438 to 569 lb/yd^3. Occasionally mixes with additional cement were used. From the test results reported in Table A7 the average value of the compressive strength at 28 days was 3515 psi for the mass concrete and 4045 psi for the structural (face) concrete.

7.4 Defects. - Information not available.

7.5 Instrumentation. - Information not available.

7.6 Comments - None

7.7 Reference - Report 56-42 Summary of concrete studies.

Central Records File	14-7-245-10	Concrete inspectors
	to 14-7-245-35	daily reports.
	14-7-253-463	
	to 14-7-253-466	
	14-7-253-457	
	14-7-253-452	Concrete test results.
	to 14-7-253-468	
	14-7-270-1358	

8. Miscellaneous

8.1 References

Central Records File	14-7-246-37	General files.
	to 14-7-246-48	
	14-7-253-435	
	to 14-7-253-441	

9. Post-Construction Investigations

9.1 Investigations

9.1.1 Long-Term Concrete Tests - Concrete cylinders were prepared during construction for testing at various periods up to 100 years. The test results to date (up to 15 years) are given in Table A8. Each value is the average of 4 cylinder tests unless otherwise noted. The specimens reached their maximum compressive strength after about 5 years.

9.1.2 Condition of Concrete in the Ice Sluice Piers (1960) - There was some concern about the quality of concrete in the filler pours for the No. 2 ice sluice piers. This was because heating elements had accidentally been left on for several months after the concrete had been placed. Six inch drill cores from the piers indicated that the concrete was homogeneous, sound and had a compressive strength of approximately 3000 psi.

9.1.3 Waterstop Shrinkage (1978) - Tests were conducted to determine the amount of shrinkage with time of samples of waterstop taken from the canal division closure structure. The results were compared to samples obtained from Thunder Bay. The average shrinkage of the waterstop from this station was found to be 2.9% for the first sample and 3.6% for the second sample.

9.1.4 Dam Deformation Study (1981) - A study was carried out to determine the causes of the apparent deformation of the throat rings. The deformation was thought to be caused by either the expansion of the concrete as a result of the concreting materials reacting or from external forces acting on the dam. In some areas of the throat rings in Units 2 and 9, there was a lack of bonding between the concrete/grout and the grout/steel interface, but it was felt that this may not have been of any structural significance.

Report 81-320 concluded from reactivity tests performed on the aggregate used in the concrete for R.H. Saunders GS that the materials were behaving normally, but that the testing should be continued.

9.1.5 In Situ Stress Measurements (1981) - A study was conducted to determine whether there were any unusual stress levels in the concrete and foundation rock under the dam. This study was conducted as part of the investigation into the apparent distortion of the throat rings. It was recommended that a detailed stress analysis should be conducted by a structural design expert.

9.1.6 Monitoring of Concrete (1982) - The concrete was monitored and tests were performed in the laboratory to determine whether there was any unusual expansion of the concrete. It was concluded that the aggregates were not showing signs of being reactive, but that the testing and monitoring should continue.

9.2 Reference-Report M60-49 Condition of concrete in ice sluice piers.
78-594-K Waterstop shrinkage.
81-320-H Dam deformation study.
81-375-H In situ stress measurement.
S83-20-H Long term concrete tests.
83-76-H Monitoring of concrete.

Table A1
R.H. Saunders GS

Chemical Composition and Physical Properties of Cement

Sample Number	CL49753	CL53916	CL55250
Composition (% by weight)			
SiO_2	20.8	20.4	20.0
Fe_2O_3	2.72	2.51	2.51
Al_2O_3	6.94	6.74	6.74
CaO	63.6	64.4	64.5
MgO	1.9	1.9	1.8
SO_3	2.5	2.1	2.1
Na_2O	0.46	0.47	0.50
K_2O	0.79	0.78	0.81
Loss on ignition	1.0	0.9	0.9
Total	100.71	100.2	99.9
Compound Composition %			
$4CaO\ Al_2O_3\ Fe_2O_3$	8.4	8.4	7.6
$3CaO\ Al_2O_3$	11.9	13.8	13.6
$3CaO\ SiO_2$	46.7	49.3	52.2
$2CaO\ SiO_2$	24.6	20.2	18.1
$CaSO_4$	4.0	4.3	3.6
% Retained on No. 200 Sieve	9.4	6.2	11.0
Blaine Air Permeability cm^2/g	--	2780	2820
Autoclave Expansion %	0.216	0.176	0.296
Time of set initial (hr:min)	2:50	2:15	1:50
final (hr:min)	4:25	4:05	4:00
Strength Tests (psi)	Tension	Compression	Compression
3-day	292	3045	2360
7-day	382	3855	3050
28-day	435	4760	3970

Reference - Concrete Laboratory File 452.2.1
C.L. Cards

Table A2
R.H. Saunders GS

Physical Properties of Manufactured Sand

Type of Material		Manufactured Sand*	Blended Sand (Manufactured and natural sand)
Sieve Size		% Passing	% Passing
	3/8"	100.0	100.0
	No 4	97.1	97.7
(Assume 100%)	No 4	100.0	100.0
	No 8	86.8	85.5
	No 14	62.1	64.0
	No 28	38.8	47.5
	No 48	20.7	25.7
	No 100	8.6	6.0
Fineness modulus (F.M.)		2.84	2.71
Specific Gravity (Apparent)		2.70	2.73
Absorption %		0.95	0.97
Sodium Sulphate Test % Weight Loss after 5 cycles		2.43	4.37

* Average of 3 test results

Reference - Concrete Laboratory File 51.2.4

Table A3
R.H. Saunders GS

Physical Properties of Coarse Aggregate*

Size of Crushed Rock		3/4" max	1-1/2" max	3" max
			% Passing	
Screen Size	3"	--	--	97
	1-1/2"	--	96.6	22.3
	3/4"	97.2	32.3	5.8
	3/8"	26.6	5.4	2.5
	No. 4	4.8	2.0	1.3
Number of Tests		629	630	381
Specific Gravity (Apparent)		2.73	2.74	2.71
Percent Absorption		0.42	0.37	0.32
Sodium Sulphate Test				
% Weight Loss After 5 cycles		2.64	7.38	10.57

* The results for the specific gravity, % absorption and sodium sulphate test are the average of 3 tests performed on the 3/4" and 1-1/2" rock and of 2 tests performed on the 3" rock. These tests were conducted by the Civil Research Department.

Reference - Central Records File 14-7-245-6
Concrete Laboratory File 51.2.4

Table A4
R.H. Saunders GS

Fly Ash Test Results

Sample	No 1	No 2
Blaine Air Permeability cm^2/g	3313	3477
Specific gravity	2.23	2.22
Loss on ignition %	4.68	4.90
Compressive Strength (psi) (average of 9-2" cubes)		
7-day Control Specimen	2835	2955
Test Specimen*	2510	2520
% control	88.5	85.4
28-day Control Specimen	3625	3720
Test Specimen*	3395	3575
% Control	93.7	96.1

Note
- Sample No 1 is the average of tests CL 53696, CL 54037, CL 54495
- Sample No 2 is the average of tests CL 56080, CL 56290, CL 57055
*Test specimens had 20% of the cement replaced with fly ash

Reference-Report MM57-1, MM57-21
MM57-3, MM57-25
MM57-4, MM58-11

Table A5
R.H. Saunders GS

Specified Concrete Design Criteria

Type of Concrete	Unit Wt lb/ft^3	Water/Cement Ratio (w/c)	Compressive Strength Design (psi)	Compressive Strength Avg 28-day Test (psi)
Mass Concrete				
- Interior or Exposed Under Water	145	0.67 - 0.70	2500	2720
- Exposed to Air	145	0.57 - 0.60	2500	2720
- Water line	145	0.50	2500	2720
Structural Concrete (Face)				
- Exposed to Air	--	0.57 - 0.60	3000	3450
- Water line	--	0.50	3000	3450

Reference - Report 56-186

Table A6
R.H. Saunders GS

Concrete Mix Proportions for 1 yd^3

Type of Mix	Mass (Interior)	Mass (Exterior)	Structural (Face)	Structural Waterline (Face)	Fine Stone Mix
Weight (lbs)					
Water	235	240	265	275	325
Cement	365	437	480	550	570
Sand	1195	1130	1225	1140	1345
3/4" stone	440	420	800	600	1635
1-1/2" stone	885	880	1220	995	--
3" stone	885	880	--	400	--
Air Content (%)	5.0	5.0	5.0	5.0	5.0
w/c Ratio	0.64	0.55	0.55	0.50	0.57

Reference - Central Records File 14-7-245-10 to 14-7-245-35

Table A7
R.H. Saunders GS

Concrete Test Results*

Cement Content of Mix lbs (bg)		Compressive Strength 7-day No. of Tests	7-day Avg (psi)	28-day No. of Tests	28-day Avg (psi)	w/c Ratio	Air %	Unit Weight (lb/ft^3)
350	(4.0)	243	2670	352	3235	0.66	5.2	146.7
372	(4.25)	284	2960	283	3375	0.64	5.1	146.6
394	(4.5)	283	3490	301	3871	0.57	5.0	149.1
438	(5.0)	110	3470	122	3994	0.56	4.4	148.5
482	(5.5)	100	3480	269	3986	0.55	5.1	147.9
503	(5.75)	--	--	113	3901	0.56	5.1	147.5
525	(6.0)	187	3520	227	4175	0.54	5.0	147.5
569	(6.5)	18	3640	22	4276	0.52	5.4	145.9

*Note:
- the averages for the water/cement ratio, air content and unit weight were obtained using the same number of tests as used to determine the average 28-day strength
- for the 7-day strength one cylinder was used for each test
- for the 28-day strength two cylinders were used for each test

Reference - Central Records File 14-7-253-454

Table A8
R.H. Saunders GS

Long-Term Concrete Tests

Class		Mass	Structural (Face)	Structural (Fly ash) (Face)	Waterline
Date Cast		26/04/57	02/07/57	20/08/57	24/08/57
Mix Proportions for 1 yd^3					
Cement	lb	365	500	395	570
Fly Ash	lb	--	--	130	--
Water	lb	235	275	290	285
Sand	lb	1195	1210	1170	1180
3/4" Crushed Rock	lb	440	785	760	765
1-1/2" Crushed Rock	lb	885	1180	--	1145
3" Crushed Rock	lb	885	--	--	--
w/c ratio		0.65	0.55	0.56	0.52
% Air		5.2	5.9	5.5	6.0
Unit Weight lb/ft^3		149.4	150	146.8	148.9
Compressive Strength psi (Average of 4 tests)					
7 day		2865	3295	2390	3505
28 day		3905	3670	3035*	4660
90 day		3975	4910	4150	--
1 year		5170	5570	4609	5655
3 year		5320	5670	4815	5775
5 year		4840	5805	4705	5540
10 year		4370	5560	4580	5570
15 year		4390	5370	4520	5290

* Average of two tests

Reference - Report S83-20-H

APPENDIX B

IROQUOIS DAM - MATERIALS SUMMARY

APPENDIX B

IROQUOIS DAM

Constructed 1956 (around this period) River System - St Lawrence

The only information on the construction of this dam is stored in Central Records File No. 14-7-253-438 and consists of two concrete control reports (April, August 1956) issued by Uhl, Hall and Rich Engineers. This firm was involved in the construction of the American portion of the St. Lawrence Power Project. The materials summary is based solely on these two reports.

1. Cement

1.1 Type - ASTM Type II Portland Cement (equivalent to CSA Type 20 Moderate Low Heat Cement).

1.2 Source - Hudson N.Y. brand name "Atlas".
Jamesville N.Y. brand name "Alpha".

1.3 Physical Properties - Information not available.

1.4 Comments - None

1.5 References - Central Records File 14-7-253-438.

2. Fine Aggregate

2.1 Source - Blend of manufactured and natural sands.

2.2 Physical Properties - Table B1 contains the average sand gradings obtained from 38 tests conducted in April and August 1956.

2.3 Preparation - Information not available

2.4 Comments - During April and August 1956 the fineness modulus ranged from 2.50 to 2.96 with an average value of 2.75.

2.5 Reference - Central Records File 14-7-253-438.

3. Coarse Aggregate

3.1 Source - Crushed dolomite from Daggett lease.

3.2 Physical Properties - The average gradings of the crushed rock tested during April and August 1956 are given in Table B2. Four sizes of coarse aggregate were used on this project (3/4", 1 1/2", 3", 6").

3.3 Preparation - Information not available.

3.4 Comments - none

3.5 Reference - Central Records File 14-7-253-438.

4. Admixture

4.1 Type - Protex (air-entraining agent).

4.2 Comments - Protex was added as required to obtain the proper air content.

4.3 Reference - Central Records File 14-7-253-438.

5. Fly Ash - Information not available.

6. Water - Information not available.

7. Concrete

7.1 Classes - Interior (mass) and Exterior (face).

7.2 Mixes - Table B3 contains examples of typical mix proportions used on this project. The mixes were classed as interior (mass) or exterior (face) and further broken down by the maximum size of aggregate used. The exterior (face) concrete contained about 400 lb/yd^3 of cement and had a water cement ratio of 0.45. Interior (mass) concrete contained about 300 lb/yd^3 of cement and had a water cement ratio of 0.52. These results were obtained from a very limited number of samples.

7.3 Strength Results - Information not available.

7.4 Defects - Information not available.

7.5 Instrumentation - Information not available.

7.6 Comments - None

7.7 Reference - Central Records File 14-7-253-438.

8.0 Miscellaneous - Information not available.

9.0 Post Construction - Information not available.

Table B1

Iroquois Dam
Grading of Sand

Sieve Size	% Passing
No. 4	98.2
No. 8	83.2
No. 16	65.7
No. 30	48.4
No. 50	21.3
No. 100	7.8
No. 200	3.9
Fineness Modulus (F.M.)	2.75
Number of Samples	38

Reference - Central Records File 14-7-253-438

Table B2

Iroquois Dam
Grading of Coarse Aggregate

Screen Size	Size of Aggregate			
	3/4"	1 1/2"	3"	6"
		% Passing		
6"				96.9
4"				53.6
3"			92.4	7.9
2"			36.2	
1 1/2"		90.0	5.2	
1"		45.4		
3/4"	90.7	10.7	1.1	
3/8"	25.1	0.5		
3/16"	3.2			
Number of Samples	39	39	18	5

Reference - Central Records File 14-7-253-438

Table B3

Iroquois Dam
Typical Mix Proportions

Class of Mix		Exterior (Face)			Interior (Mass)	
Size of Aggregate		Max 1 1/2"	Max 3"	Max 6"	Max 3"	Max 6"
Mix Design (yd^3)						
Cement	lb	513	400	383	297	289
Water	lb	247	192	154	166	157
w/c Ratio		0.48	0.48	0.40	0.56	0.54
Sand	lb	1020	960	1000	1137	980
3/4" rock	lb	1053	790	637	766	627
1 1/2" rock	lb	1125	788	500	567	520
3" rock	lb	-	1088	683	1284	650
6" rock	lb	-	-	1017	-	1096
Entrained Air	%	5.0	4.2	2.5	5.0	3.3
Unit Weight lb/ft^3*		150.0	157.5	157.0	154.0	155.8

Reference - Central Records File 14-7-253-438

* The unit weight values appear to be higher than normal.

APPENDIX C

ARNPRIOR GS - MATERIALS SUMMARY

APPENDIX C

ARNPRIOR GS - MATERIALS SUMMARY

Constructed 1973 - 1976 River System - Madawaska

This station was constructed by Acres Consulting Services Limited. Most of the information on the materials used in the construction can be found in the report "Concrete Quality Control Report" issued by Acres. Additional information consists of reports on the aggregate search and the testing of fly ash and cement.

The concrete on this project was mainly placed under two contracts. Contract C-3 took place in 1973 and Contract C-5 took place during 1974-1976.

1. Cement

1.1 Source - Lake Ontario Cement Limited, Picton Mill.

1.2 Type - Type 10 Normal Portland Cement.

1.3 Physical Properties - Table C1 contains the physical and chemical properties of the cement. These are the results of tests performed by the manufacturer on 9 samples representing about 5800 tons of cement.

1.4 Comments - All the cement used on this project met the CSA-A5 specifications. Some physical testing was conducted by Ontario Hydro in the Civil Research Department. The chemical analysis and physical tests were performed mainly by the manufacturer.

1.5 References - Project File 842 ARN - Acres quality control report.
Central Records File 5-8-116-1 - Cement test reports.
Concrete Laboratory File 89.1.1 - Cement test reports.

2. Fine Aggregate

2.1 Source - Riddell pit at Galleta.

2.2 Physical Properties - Table C2 contains the physical properties of a sand sample from the Riddell pit obtained during the aggregate survey. Petrographic numbers for samples of sand taken from this pit are given in Table C3.

2.3 Preparation - The oversized material was removed and the sand was stockpiled at the pit for later delivery to the site.

2.4 Comments - During periods of fine aggregate production the sand was tested daily for gradation and organic content. Throughout the job the grading of the sand was consistent with the fineness modulus (F.M.), usually about 3.00. The petrographic number for a sample of sand from a pit on the Riddell property was determined to be 118 for the No. 16 and

No. 30 fractions.

2.5 References - Report S73-53-K Petrographic numbers.
Concrete Laboratory File 89.1.1
Project File 842 ARN-Acres quality control report.

3. Coarse Aggregate

3.1 Source - Braeside quarry at Braeside.

3.2 Physical Properties - The Braeside quarry consisted of microcrystalline limestone. This rock was crushed into two sizes of coarse aggregate (1 1/2", 3/4"). The physical properties of this material are given in Table C4. The petrographic number for a sample of the 3/4" rock is given in Table C5.

3.3 Preparation - The rock was quarried, crushed into two sizes and stockpiled at the quarry for later delivery. The material was screened and washed immediately prior to being delivered to the batch plant holding hoppers. This removed the particles smaller than 3/16".

3.4 Comments - The aggregate was checked regularly during production or when producing concrete. The gradings throughout the job were generally consistent. The petrographic number for this material was found to be 120 from a test on a 3/4" aggregate sample.

The quarry contained thin shaly beds which made up less than 1% of the quarry face. It was felt that this material would be lost as fines during the blasting and crushing operations.

3.5 Reference - Report S76-10-H Petrographic examination.
Concrete Laboratory File 89.1.1.
Project File 842 ARN - Acres quality control report.

4. Admixtures

4.1 Type - Contract C3 1973 Pozzolith 80 - water-reducing admixture
MBVR (Master Builders Vinsol Resin)
- air-entraining admixture.
Contract C4 1974 - 1976
MBL (Master Builders Lignin) - water-reducing admixture.
Darex - air-entraining admixture.

4.2 Comments - The admixtures were used in the following quantities.

Pozzolith 80 5 to 6.5 oz/100 lb cementing materials

MBVR	as required
MBL	6 fl oz/100 lb cementing materials
Darex	as required

The amount of air-entraining admixture required fluctuated with the amount of fly ash used and the carbon content of the fly ash.

4.3 Reference - Project File 842 ARN-Acres quality control report.

5. Fly Ash

5.1 Source - Trenton Channel Power Plant, Detroit Edison Company, Trenton, Michigan.

5.2 Physical Properties - Table C6 contains the physical properties of the fly ash from tests performed by the Civil Research Department. These results were obtained from 13 test reports.

5.3 Comments - Fly ash was used as a 20-30% replacement for the cement in some mixes. The carbon content of the fly ash fluctuated over a wide range which caused problems in controlling the air content of the concrete. Carbon analysis was conducted regularly at the Trenton Channel Plant. When poor material was identified, its location in the silo was monitored so that problems could be anticipated and prepared for.

5.4 References - Project File 842 ARN-Acres quality control report.
Central Records File 14-7-265-1058 Fly ash test results.
14-7-265-1056 Fly ash test results.
14-7-265-1055 Fly ash test results.
5-8-116-3 Fly ash test results.
Laboratory File 89.1.1 Fly ash test results.

6. Water - Obtained from the Town of Arnprior domestic water supply.

7. Concrete

7.1 Classes - There were five basic classes of concrete. The design specifications and mix requirements are given in Table C7. The design strengths varied from 3000 psi to 5500 psi.

7.2 Mix - The proportions of the mixes were altered depending on the condition of the aggregate. Fly ash was sometimes used as a replacement

for a portion of the cement. Table C8 contains typical mix proportions for the various classes of concrete.

7.3 Strength Results - In 1973 under contract C-3 the concrete placed was mainly Class 1 (mass) and Class 3 (Structural). The average strength for Class 1 was 3740 psi and for Class 3 was 4440 psi. Under contract C-5 in 1974-1976 Class 1 (mass) and Class 2 (face) concretes gained strengths of 3468 psi and 3875 psi respectively. A summary of the results of the tests on selected classes of concrete is given in Table 9.

7.4 Defects - No information available.

7.5 Instrumentation - No information available.

7.6 Comments - The inspection of the concrete for this station was conducted by Acres Consulting Services Ltd. Some testing of aggregates, cement and fly ash was performed by the Civil Research Department.

7.7 References - Project File 842 ARN-Acres quality control report.

8. Miscellaneous - Central Records Files 14-7-265-1055 General files.
14-7-265-1056
14-7-265-1058

9. Post-Construction Investigation - No information available.

Table C1

Arnprior GS

Cement

Physical Properties		Chemical Properties	
% Retained on Sieve No. 200	2.43	Composition	(% by weight)
Blaine cm^2/g	3384	SiO_2	20.65
Time of Set (Vicat)		Al_2O_3	5.87
Initial (hr:min)	1:55	Fe_2O_3	2.37
Final (hr:min)	3:40	CaO	63.24
Autoclave Expansion %	.082	MgO	2.24
		SO_3	3.10
Compressive Strength		Na_2O	0.18
		K_2O	1.07
3-day (psi)	2892	Loss on Ignition	1.25
7-day (psi)	3586	Total	99.97
28-day (psi)	4686		
Heat of Hydration		Compound Composition %	
7-day cal/gr *	73.6	C_3S	48.89
28-day cal/gr *	79.9	C_2S	22.33
		C_3A	11.53
		C_4AF	7.22

* Test on One Sample

Reference - Project File 842 ARN
Concrete Laboratory File 89.1.1

Table C2

Arnprior GS
Physical Properties of Fine Aggregate

Sieve Size	% Passing
3/8"	100
No. 4	96
No. 8	84
No. 16	61
No. 30	34
No. 50	14
No. 100	4
Fineness Modulus (F.M.)	3.08
Bulk Specific Gravity	2.67
% Absorption	1.34
Mg. Soundness Test	
% Loss After 5 cycles	15.0

Reference - Concrete Laboratory File 89.1.1

Table C3

Arnprior GS
Petrographic Numbers on Sand

Source of Sample	Petrographic Number for Fraction		
	Sieve Size		
	No. 16	No. 30	No. 8 to No. 100
Riddell Pit	116.5	110.0	107.3
Riddell Pit	117.0	107.0	-
Riddell Pit (Batching Plant)	131.0	107.5	-
Riddell Property - Galletta Pit	116.5	119.5	-

Reference - Report S73-53-K

Table C4

Arnprior GS
Physical Properties of Coarse Aggregate

Material Size	1 1/2" to 3/4"			3/4" to No. 4		
	Spec. Limit	Job		Spec. Limit	Job	
Screen Size		Avg.	Range		Avg.	Range
	% Passing			% Passing		
2"	100	100	100	-	-	-
1 1/2"	90 - 100	95	93 - 100	-	-	-
1"	25 - 55	55	52 - 60	100	100	100
3/4"	0 - 15	5	2 - 8	90 - 100	93	92 - 96
1/2"	-	-	-	-	50	45 - 55
3/8"	0 - 5	2	0 - 4	20 - 55	12	12
No. 4	-	-	-	0 - 5	2	2 - 4

Bulk Specific Gravity - 2.68
% Absorption - 0.57
Mg Soundness test
% Loss after 5 cycle, 1 1/2" max - 3.1
3/4" max - 6.9

Reference - Concrete Laboratory File 89.1.1

Table C5

Arnprior GS
Petrographic Numbers on Coarse Aggregate

Screen Size	3/4"	1/2"	3/8"	No.4
% Retained	14.0	51.6	19.2	15.2
No. of Pieces	200	200	200	200
Petrographic Number	126.0	115.0	124.5	123.0

Petrographic number for the entire sample = 120

Reference - Report S76-10-H

Table C6

Arnprior GS
Physical Properties of Fly Ash

	Average Test Result(1)	Specified Limits
Moisture Content %	0.11	3.0 (max)
Loss on Ignition %	5.73	8.0 (max)(2)
		5.0 (max)(3)
Air-Entraining Admixture (ml for 18% Air)	2.3	1.7 to 2.7
*Blaine cm^2/cm^3	7610	6500 (min)
% Retained on No. 325 Sieve (4)	14.64	20 (max)
Multiple Factor	87	150 (max)
Specific Gravity	2.29	-

(1) Average of 13 test results
(2) Maximum as specified in contract C-3
(3) Desired limit for air-entraining agent control
(4) Corrected to NBS Residue on No. 325 Bronze Cloth Value

*The Blaine was recorded as area per unit volume rather than per unit mass as is usually done.

Reference - Project File ARN.

Table C7

Arnprior GS
Concrete Classes

Class	Specified Strength (psi)	Max Aggr. Size	Max Slump	Air %
1 (Mass)	3000	1 1/2"	3"	4 - 6
2 (Face)	3000	3/4"	4"	5 - 7
3 (Str w/L)	4000	1 1/2"	3"	4 - 6
4 (Str w/L)	5500	3/4"	4"	5 - 7
5 (Fill)	2000	1 1/2"	2" - 3"	4 - 6
6 (Deck)	4000	3/4"	4"	5 - 7

Reference - Project File 842 ARN

Table C8

Arnprior GS
Concrete Mix Proportions

Class	Water lb.	Cement lb.	W/C Ratio	Sand lb.	3/4" Aggr. lb.	1 1/2" Aggr. lb.	Fly Ash % Replacement of Cement *
1	235	413	0.57	1360	990	990	0, 20, 30
2	230	405	0.57	1600	1670	0	0, 20
3	225	520	0.43	1280	990	990	0, 20, 30
4	265	735	0.36	1230	1700	0	0, 20
5	235	309	0.76	1450	990	990	0, 20, 30
6	Proportions Varied						

* Note Percentage of cement replaced with fly ash.

Reference - Project File 842 ARN

Table C9

Arnprior GS
Concrete Test Results

Class	Design Strength psi	No. of Tests	Average Strength psi	Coef. of Variation %	Standard Deviation psi	Average Range psi	Within Test Coef. of Var. %	Within Test Std. Dev. psi
Contract C-3 1973								
1	3000	56	3738	9.7	355	-	4.6	176
3	4000	62	4440	15.3	653	-	3.9	173
Contract C-4 1974 - 1976								
1	3000	273	3468	7.5	257	111	2.8	99
2	3000	225	3875	8.2	312	125	2.9	110
3	4000	59	4473	7.3	328	145	2.8	128
4	5500	12	5830	-	-	-	-	-
6	4000	108	4793	6.6	288	168	3.5	149

Note: Class 2, 4 and 5 concrete was placed under contract C-3, but not in large quantities. Under contract C-4 a small amount of Class 5 concrete was placed.

Reference - Report File 842 ARN

APPENDIX D

STEWARTVILLE GS - MATERIALS SUMMARY

APPENDIX D

Stewartville GS - Materials Summary

Constructed 1946 - 1950

River System - Madawaska

Most of the information on the construction of this station is contained in a report (History File) prepared by the Civil Research Department at the time this dam was built. Additional information is stored in Central Records and in Research Division Reports issued on this project.

An extension was added to this station in 1967-1968. A summary of the materials used in this work is contained in Appendix J.

1. Cement

1.1 Source - Canada Cement Company, Hull Mill.

1.2 Type - Type 10 Normal Portland Cement.

1.3 Physical Properties - Table D1 contains test results and the chemical composition of typical samples of cement.

1.4 Comments - A small amount of cement was used from other sources, but not in any significant quantities.

1.5 References - Concrete Laboratory File 452.2.1 - Chemical analysis.
Concrete Laboratory C.L. Cards

2. Fine Aggregate

2.1 Source - McLaren's pit
- Natural sand and gravel deposit.

2.2 Physical Properties - Table D2 contains the average grading of the fine aggregate sampled from the pit (after screening) and from the mixing plant. An average of 9% oversized material was present in the sand.

2.3 Preparation - The material from the pit was screened to separate the stone and sand and then stockpiled at the mixing plant. Some additional fine aggregate was obtained from the crushing of the stone.

2.4 Comments - McLaren's pit supplied all the aggregate for this project. The sand content of the deposit varied with depth, but averaged about 46%.

2.5 References - Report LO40184 (01/03/46) - Aggregate survey
(01/04/46)
History File

3. Coarse Aggregate

3.1 Source - McLaren's pit.
Natural sand and gravel deposit.

3.2 Physical Properties - Table D3 contains typical gradings of the coarse aggregate.

3.3 Preparation - The pit run material was screened to separate the sand and gravel. The oversized stone was separated and crushed. At the batching plant the stone was screened into 3 sizes.

3.4 Comments - On some occasions the aggregates would get mixed up and placed in the wrong bins. The aggregate stock piles were placed close together and this would also cause them to mix.

A problem developed with a shortage of medium gravel. The initial mix proportions called for more coarse gravel than could be weighed on the scales at the mixing plant. The excess coarse gravel was replaced with medium stone. Also, a large amount of the structural concrete was placed by pump which meant that no coarse gravel could be used. Both of these conditions resulted in more medium gravel being used than had been orginally anticipated.

3.5 References - Report L.O. 40184 (01/03/46) Aggregate survey.
(01/04/46)
History File

4. Admixtures

4.1 Not used on this project except as noted in Section 4.2.

4.2 Comments - A test was conducted on air-entraining admixtures in June 1948. Darex and Pozzolith were used during the placing of Section 5 of the north training wall of the spillway channel.

4.3 Reference - History File

5. Fly Ash - not used on this project.

6. Water - information not available.

7. Concrete

7.1 Classes - The basic classes of concrete were face with a specified strength of 3000 psi and mass with a specified strength of 1750 psi.

7.2 Mixes - The face concrete generally contained 462 lb/yd^3 of cement, but on some occasions this was increased to 525 lb/yd^3. The mass concrete contained about 332 lb/yd^3 of cement. The main piers of the headworks used a special 5000 psi mix with 630 to 700 lb/yd^3 of cement. A porous concrete mix was used to some extent along the rock that intersected the horizontal drains in the main dam.

Table D4 contains the basic mix proportions used on this project. The grading of the coarse aggregates varied depending on the material available.

7.3 Strength Results - Table D5 contains the results of concrete tests performed during construction. The main dam was made up of approximately 35% mass concrete and 65% face concrete. The compressive strength at 28 days for the mass concrete was 2640 psi and for the face concrete was 4200 psi. The unit weight of the concrete in the main dam was 149.5 lb/ft^3 and in the powerhouse was 152.5 lb/ft^3.

7.4 Defects - The location of all cracks on the downstream face of the dam noticed during construction is shown on drawings in the History File. Honeycombing was chipped out and repaired; bulges were removed and bolt holes were dry packed.

An ultrasonic investigation was conducted in 1948 (Report LO1544) on some major cracks in Sections 6, 7 and 8 that occurred during construction. The largest crack was located in the walls, ceiling and floor of the inspection tunnel running into the elevator shaft of Section 7. Two cracks were in the south face of Section 6 and two in the north face of Section 8. The report concluded that the crack in Section 7 was at least 3' deep and should be investigated further. The cracks in Sections 6 and 8 were believed to be not more than a maximum of 8' deep and in most places not more than 4' deep.

7.5 Instrumentation - A total of 317 instruments were placed in the dam between Section 7 and 15 with most being placed in Section 11 and 12. The leads for these instruments terminate in junction boxes in the main dam inspection tunnel. A breakdown of some of the various instruments is given below.

153	resistance thermometers
53	jointmeters
6	shearmeters

4 stressmeters
72 crackmeters
27 strainmeters

7.6 Comments - The mixing plant never reached the minimum estimated rate of concrete production. This resulted in the concrete being placed at a lower rate than was orginally planned and in some cases the method of placing had to be modified.

The concrete in the dewatering tunnel was placed by the Prepakt company. The Prepakt method of concrete placing consisted of placing the coarse aggregate in the forms and then injected grout into the forms.

7.7 References - Report LO 1544 Crack investigation
Central Records File 14-7-253-423 to 14-7-253-429 - Concrete test results and a few random concrete inspectors daily reports.
History File

8. Miscellaneous

9. Post-Construction Investigation

9.1 Investigations

9.1.1 Long-Term Concrete Tests - Table D6 contains the results to date (up to 25 years) of tests on the concrete cylinders cast during construction. Each result is the average of tests on 3 cylinders. The compressive strength tended to increase until the last test (25 year) when it decreased slightly.

9.1.2 Soniscope Investigations of Cracks 1951 - Soniscope tests were conducted on cracks on the downstream face of Sections 11, 12 and 13 on a regular basis from 1949 to 1951. Report 52-43 concluded that initially there was a reduction in crack depth based on the overall average crack depth. Additional reductions were not noticed in the subsequent investigations.

Two vertical holes were drilled in the main dam and Soniscope investigations conducted using these holes. In Report 54-586 which covers results obtained in 1953, it was concluded that there was no indication of extensive cracking that would affect the structural stability of the dam. A small area that contained concrete of doubtful quality or continuity was detected.

9.1.3 Tests on Concrete Cores (Main Dam) - Tests were conducted on concrete cores from two 6" diameter holes drilled in Section 12 of the main dam. (Cores obtained in 1952, tests reported 1956.) Table D7 summarizes

the results from these tests. The compressive strength of the mass concrete was tested at 2565 psi and the face concrete was tested at 4240 psi. Additional results are given in Report M56-33 and the freeze/thaw testing is covered in Report M56-67.

9.1.4 Uplift Pressure on Main Dam - Results of an investigation of uplift pressure on the main dam are recorded in Report 55-446. Readings were taken annually from 1951 to 1955. An increase in uplift pressure was noted at one cell. This was thought to have been caused by the foundation drain becoming plugged or the flow of leakage water having increasing.

9.1.5 Leakage Into the Inspection Tunnel - The quantity of water leaking into the inspection tunnel had increased during the period 1952-1956. The source of this water was unknown. Since no build-up of pressure was noted from the uplift cells, it was thought that the leakage was confined to the vertical construction joints. The leakage was concentrated between Stations 4+64 and 5+84.

9.1.6 Treatment of Dam Foundation Leakage - In 1983 and 1984 two zones of major leakage under the main dam were sealed using hot asphalt and conventional cement grouts.

9.2 References

Report No 52-43 Soniscope crack investigation.
54-586
M56-33 Tests on concrete cores from main dam.
M56-67
55-446 Uplift pressure on main dam.
57-370 Leakage into inspection tunnel.
S83-20-H Long-term concrete tests.

Project Files 842.STEW-Treatment of dam foundation leakage.

Table D1
Stewartville GS

Chemical Composition and Physical Properties of Cement

Sample Number	CL 12954	CL 13047	CL 16630
Composition (% by weight)			
SiO_2	20.64	21.56	19.68
Fe_2O_3	3.15	3.00	2.74
Al_2O_3	6.13	5.32	6.54
CaO	62.64	63.36	62.90
MgO	3.32	3.21	3.20
SO_3	1.75	1.79	2.18
Na_2O	0.64	0.57	0.46
K_2O	0.66	0.56	0.57
Loss on Ignition	0.90	1.10	0.91
Total	99.83	100.47	100.07
Compound Composition %			
4 $CaO.Al_2O_3.Fe_2O_3$	9.5	9.1	8.4
3 $CaO.Al_2O_3$	10.9	9.0	12.7
3 $CaO.SiO_2$	54.5	49.0	52.4
2 $CaO.SiO_2$	18.0	25.0	16.5
$CaSO_4$	3.0	3.0	3.7
% Retained on No 200 Seive	5.9	7.5	7.6
Normal Consistency	24.0	23.0	23.0
Time of Set Initial (hr:min)	2:55	2:40	2:40
Final (hr:min)	5:15	5:50	5:25
Tensile Strength (psi)			
3-day	340	267	290
7-day	341	378	303
28-day	398	470	453

Reference - Concrete Laboratory File 452.2.1
C.L. Cards

Table D2
Stewartville GS

Summary of Sand Gradings

Source of Test Sample	Pit Hopper (After Screening)	Mixing Plant
No. of Tests	681	258
% Passing Sieve No.		
No. 8	87	88
No. 14	70	72
No. 28	44	45
No. 48	15	19
No. 100	5	6

Reference - History File

Table D3
Stewartville GS

Gradings of Coarse Aggregate

Source of Sample	Pit Hopper (After Screening)	Mixing Plant		
		Fine Stone	Medium Stone	Large Stone
Size of material		3/4" max	1-1/2" max	3" max
Screen Size		% Passing		
3"	95			88
1-1/2"	62		68	12
3/4"	29	82	4	3
3/8"	8	21	2	2
No. 4	2	5	1	1

Reference - History File

Table D4
Stewartville GS

Concrete Mix Proportions*

Type of Mix	Mass	Face	Face (for Pumpcrete)
Proportions for 1 yd^3			
Cement lb	332	462	462
Water (total) lb	270	287	287
Sand lb	1515	1390	1390
Fine gravel (3/4" max) lb	480	470	1000
Medium gravel (1-1/2" max) lb	565	550	1000
Coarse gravel (3" max) lb	1000	1000	--
w/c	0.81	0.62	0.62

* Moist weight of the coarse aggregates is given

Reference: History File

Table D5
Stewartville GS

Summary of Concrete Tests

Location	Main Dam		Powerhouse*
Class of Concrete	Mass	Face	Face
No of Cylinders	178	260	142
Compressive Strength (psi)			
7 day	1800	3180	2930
28 day	2640	4200	3960
w/c Ratio	0.72		0.64
Unit wt. lb/ft^3	149.5		152.5

*The concrete test cylinders for the Powerhouse were made of unscreened concrete (the stones over 1-1/2" had not been removed).
Reference: History File

Table D6
Stewartville GS

Long-Term Concrete Test

Class of Concrete	Core	Face
Date Cast	05/10/48	15/09/48
Mix Design for 1 yd^3		
Cement lb	334	462
Water lb	326	323
Sand lb	1414	1387
Fine Stone lb	430	448
Medium Stone lb	1550	1542
w/c Ratio	0.98	0.70
Compressive Strength (psi) (Average of 3 cylinders)		
7 days	No test	No test
28 days	2090	3640
90 days	2770	4300
1 year	2890	4950
2 years	3020	5100
3 years	3030	5150
5 years	3090	5310
10 years	2900	5360
15 years	3580	6000
25 years	3540	5870

Reference: Report S83-20-H

Table D7
Stewartville GS

Properties of Concrete Cores

Class of Concrete	Mass	Face
Compressive Strength (psi) (28-day test)	2565 (17)	4240 (6)
Unit Weight lb/ft^3		
Oven dry	145.6 (17)	147.5 (6)
Saturated	153.7 (17)	154.7 (6)
Specific Gravity - Bulk	2.48 (7)	2.48 (7)
Apparent	2.71 (7)	2.68 (7)
% Voids	8.34 (7)	7.70 (7)

Note - Numbers in brackets indicate number of samples used to obtain results.
Reference: Report M56-33

APPENDIX E

CALABOGIE GS - MATERIALS SUMMARY

APPENDIX E

Calabogie GS - Materials Summary

In-service Date - 1917 River System - Madawaska

Calabogie GS was placed in service in 1917 and acquired by Ontario Hydro in 1929. Information on the original construction could not be located.

In the 1960's some remedial work was done on this dam. A summary of the materials used for this work is located under Appendix J.

9. Post-Construction Investigations

9.1 Investigations

9.1.1 Repairs to Calabogie G.S. 1937.
Repair work was conducted on this station around 1937. The aggregate was obtained from the Milton Blair pit near Arnprior. Physical properties of the samples of the sand and gravel from this pit are given in Table E1. The recommended concrete proportions are contained in Table E2. This concrete had a design strength of 3000 psi at 7 days.*

9.1.2 Soniscope Tests-1965.
Soniscope tests were conducted on the four piers in the Stop-Log Dam at Calabogie GS in 1965. From both the test results and the general appearance, it was concluded that the concrete appeared to be in good condition. Report (66-1-H) suggested that a more likely cause for concern would be the bond of successive lifts of concrete at construction joints and fill planes. It was suggested that a diamond drill investigation be carried out.

9.1.3 Test on Concrete Cores-1967.
Six inch concrete cores were removed from Pier 4 of the North Branch Stop-Log Dam. The drilling was carried out in April 1966 and the cores were tested in March 1967. Results of compression tests on the concrete cores and the unit weights are given in Table E3. The results are very random with no apparent trend. The compressive strength ranged from 1670 to 7200 psi and the average unit weight was 148.8 lb/ft^3. It was noted during drilling that the coarse aggregate in the concrete became less abundant and smaller in size with depth.

*It should be noted that present day standards usually allow 28 days for concrete to achieve its design strength

9.1.4 Tests on Concrete Cores-1968.
A hole was drilled in the main dam 22' from the top west pier and 1 5/8" diameter concrete cores obtained. The cores were tested in March 1968. Results of these tests are contained in Table E4. The average strength of the concrete cores was found to be 2560 psi at 1 1/2' and 3200 psi at 22'. The average unit weight of the concrete was 147.8 lb/ft^3.

9.2 References - Report 66-1-H Soniscope tests on Calabogie GS
Central Records File 14-7-267-1163 General file on Calabogie GS containing results of tests on concrete cores.

Table E1

Calabogie GS
Grading of Sand and Gravel

Sieve Size	Sand (% Passing)	Gravel (% Passing)
3"		100.0
1 1/2"		87.7
3/4"		56.0
3/8"		17.6
No. 4	100	7.1
No. 8	91.0	
No. 14	76.9	
No. 28	52.5	
No. 48	26.9	
No. 100	6.2	
Finess Modulus (F.M.)	2.46	
Unit Weight (loose) lb/ft^3	84.5 (3% moisture)	109.8

Note - There was 5.2% material larger than the No. 4 Sieve in the sand at the mixing plant.
Reference - Central Records File 14-7-267-1163

Table E2

Calabogie GS
Recommended Concrete Proportions for 1 yd^3

Material		Weight
Sand	lb.	1135
Gravel	lb.	1855
Cement	lb.	700
Water	lb.	360
W/C Ratio		0.51

Reference - Central Records File 14-7-267-1163

Table E3

Calabogie GS
Tests on 6" Dia. Concrete Cores

Depth Core Was Taken	Compressive Strength psi	Unit Weight lb/ft^3
0 to 1'	1670	150.3
1'7' to 2' 7"	1920	144.6
3'1" to 4'1"	1970	149.4
4'9" to 5'9"	4420	153.9
5'9" to 6'9"	3470	151.5
7' to 8'	2690	153.0
8' to 9'	3200	151.7
9' to 10'	2990	151.0
10' to 11'	2340	139.2
11'5" to 12'5"	5350	148.6
12'5" to 13'5"	4840	145.2
14' to 15'	5000	150.1
15' to 16'	7200	151.0
16'6" to 17'6"	2790	143.3
	Average	148.8

Reference - Central Record Files 14-7-267-1163.

Table E4

Calabogie GS
Tests on 1 5/8" Dia. Concrete Cores

Depth Core was Taken	Compressive Strength psi	Unit Weight lb/ft^3
1 1/2'	2510	148.64
1 1/2'	2760	148.22
1 1/2'	2415	147.64
Average	2560	148.2
22'	3110	145.49
22'	3285	148.94
Average	3200	147.2

Reference–Central Records File 14-7-267-1163

APPENDIX F

BARRETT CHUTE GS - MATERIALS SUMMARY

APPENDIX F

BARRETT CHUTE GS - MATERIALS SUMMARY

Constructed 1941 - 1942 River System - Madawaska

Most of the information on the original construction of this station is contained in a report (History File) prepared by the Civil Research Department at the time this dam was built.

Two additional units were added in 1967-1968. The information on the materials used in this work is contained in Appendix J.

1. Cement

1.1 Source - 24% St Marys Cement Company, St. Marys, Ontario.
76% Canada Cement Company, Hull, Quebec plant.

1.2 Type - Type 10 Normal Portland Cement and modified Type 10.
(see Section 1.4)

1.3 Physical Properties - Table F1 contains typical results from tests performed on cement used on this project. Blanks in the table indicate information that was not available. Each sample tested was a blend from a number of different rail cars. The strength of the cement was measured by means of a tension test which was a common test used at the time of construction.

1.4 Comments - The normal cement was modified to try and meet the CSA requirements for Type 20 cement (moderately low heat cement). This low heat cement was ordered from Canada Cement Company, but the actual date of delivery is unknown. No apparent change was noticed in the peak temperature of the concrete.

1.5 References - History File
Concrete Laboratory C.L. cards.

2. Fine Aggregate

2.1 Source - Legree pit
- Natural sand deposit.

2.2 Physical Properties - Table F2 contains the grading of the sand used during construction. The average amount of oversized material (greater than No. 4 Sieve) at the batching hopper was 5.9%.

2.3 Preparation - The sand was washed and screened.

2.4 Comments - Initially the sand was on the coarse side, but within the specified grading. Later a seam of fine sand was encountered which

required washing in order to meet the specifications. Near the end of construction, 8349 tons of unwashed sand was mixed with the material on site and used. The average fineness modulus (FM) varied from 2.57 to 2.82.

2.5 Reference - History File

3. Coarse Aggregate

3.1 Source - Excavated rock from the canal excavation.
- Mainly red granite and green gneisses.

3.2 Physical Properties - Only one size of coarse aggregate was used. In areas containing reinforcing steel an additional 2" size sieve was used during the screening operation to obtain a finer grading. Table F3 contains the typical grading of the crushed rock. Table F4 presents the results of sodium soundness tests performed on samples of the coarse aggregate. The loose density of the crushed rock was 87 lb/ft^3.

3.3 Preparation - The excavated rock was crushed and screened.

3.4 Comments - In the excavated rock there was some black mica schist which had to be avoided. Problems were encountered with poor grading as a result of the method of stockpiling the aggregate. The crusher also broke down frequently and eventually had to be replaced.

3.5 Reference - History File

4. Admixture

4.1 Source - No admixtures were used on this project except as noted in Section 4.2.

4.2 Comment - Pozzolith was added to the last 100 yd^3 of concrete placed in the closure plugs (1 lb Pozzolith H.R. 10/bag (87.5 lbs) of cement).

4.3 Reference - Central Records File 14-7-265-1090 Report on concreting of closure plug.

5. Fly Ash - Not used on this project.

6. Water - Taken from Madawaska River 200 yds upstream from the site.

7. Concrete

7.1 Classes - Face concrete with 3000 psi specified strength and core (mass) concrete with no strength specified; however 2000 psi was assumed.

7.2 Mixes - The proportions of the design mixes were altered as the performance of the concrete was established and for various placing conditions. Table F5 contains the mix proportions used on this project. The main dam used Mix A (face) and Mix E (mass) with some Mix B (face). The powerhouse consisted mainly of Mix B (face) with some Mix A (face) used at the beginning. The headworks was made up of Mixes A and B (face). Other mixes were used for special applications such as floor finish.

7.3 Strength Results - Table F6 contains the results for all concrete cylinders tested on site during construction. The face concrete in the main dam achieved an average 28-day compressive strength of 4260 psi and the core (mass) concrete 2540 psi. The test cylinders sampled from the concrete used in the powerhouse obtained a compressive strength of 4140 psi.

7.4 Defects - There was a major fire in the headworks which damaged the concrete. Remedial work was required to repair this area. Cracks and honeycomb were observed during construction and these defects were investigated and repaired. Drawings giving the location of defects are found in the History Files.

7.5 Instrumentation - At station 5+54.5 (Block 16), 14 joint meters were installed at elevation 592 to measure or detect any vertical cracks parallel to the axis of the dam. At elevation 583, twelve Carlson stress meters were installed to measure the live load stresses as the reservoir filled. Reports on the instrumentation after installation (LO 2817-27) and after two years service (LO 4814) indicate no cracking. These reports also question the readings obtained from these meters. Temperature readings were taken at many points across Block 16 to obtain a thermal gradient. Results are given after initial placing of concrete and up to a period of two years. During construction thermometers were placed in both of the closure plugs and the second closure plug contained joint meters as well.

Table F7 lists the thermocouple readings obtained during construction. The highest recorded temperature was 164°F reached after seven days in Block 8 (Sta 2+64) at elevation 643 in the face concrete. The temperature varied depending on the type of concrete, location, time of year and size of pour.

7.6 Comments - None

7.7 References - Reports

LO 2817-27	Results of
LO 4814	instrumentation
	readings.

Central Records File	14-7-265-1086	A few random concrete inspectors daily report.
	14-7-265-1087	Record of concrete test results.
	14-7-265-1089	Results of instrumentation readings.
History File	Description of headworks fire and remedial work, sketches with location of defects and records of concrete tests results.	

8. Miscellaneous

8.1	References - Central Records File	14-7-265-1088	General files.
		14-7-265-1089	
		14-7-265-1091	

9. Post-Construction Investigations

9.1 Investigations

9.1.1 Long-Term Concrete Tests - Table F8 contains the results of the long-term concrete test performed on cylinders from this project. The compressive strength continually increased over the 15-year period of testing.

9.1.2 Stress Strain and Temperature Readings (see 7.5 Instrumentation) - After two years the temperature readings had decreased and showed only seasonal fluctuations. During this period stress and joint meters had shown no evidence of internal or vertical cracking or significant changes in stress.

9.1.3 Crack Investigation

9.1.3.1 Surface Cracks (1945) - Report LO 40084 gives a description of the surface crack investigation of the main dam and the results obtained during the testing in 1945. The average depth of the cracks was about 6.1" with a maximum depth of 37.0". Table F9 contains a summary of the results obtained during this investigation.

9.1.3.2 Internal Cracks (1947) - Report LO2812-26 describes the method used and the results obtained from a Soniscope investigation for internal cracks in the main dam in 1947. This report concluded that the readings indicated that there was no trace of internal cracks parallel to the axis of the dam. One large surface crack was detected running horizontally across Section 11 at elevation 615 and might be up to 10' deep.

9.1.4 Concrete Drill Core Investigation - Concrete cores were taken from Sections 9 and 16 of the main dam in 1945 and tested in 1950 to 1951. The concrete proved to be of good quality and fairly uniform. The concrete in the core of the dam had an average unit weight of 151.7 lb/ft^3 and an average compressive strength of 3000 psi, which was higher than that of the samples tested during construction. The face concrete had an average unit weight of 151.7 to 154.5 lb/ft^3 (depending on the elevation the core was obtained) and an average compressive strength of 3900 psi, which was lower than that of the samples tested during construction. It was suggested that this variation in compressive strength between cylinders tested during construction and the concrete cores could be partly due to the uncertainty in the location of the line dividing the face and mass classes of concrete.

9.1.5 Inspection of Concrete (1951) - In the main dam, general surface weathering was noticed with a slight increase in surface cracks in Sections 7 to 22. On the north side of the headworks, several new cracks had occurred with additional seepage from horizontal construction joints.

9.2 Reference - Report

LO 40084 Crack investigation.
LO 2812-26
52-735 Investigation of concrete.
S83-20-H Long-Term concrete tests.

Central Records File

14-7-265-1084	Drilling of main dam
14-7-265-1091	and tests on concrete cores.
14-7-265-1089	Photos of inspection and testing.

Table F1
Barrett Chute GS

Chemical Composition and Physical Properties of Cement

Sample Number	CL11449	CL11644	CL11531
Brand	Canada	Canada	Pyramid
Mill	Hull	Hull (Modified)	St Marys
All values % by weight			
Loss on Ignition	1.85	0.75	1.10
Insoluble Matter	0.10	0.15	0.05
SiO_2	20.30	20.85	21.05
Fe_2O_3	2.91	3.08	2.42
Al_2O_3	6.59	5.52	6.48
CaO	62.00	63.90	62.80
MgO	2.88	3.44	3.60
SO_3	1.85	1.62	1.82
Na_2O	0.70	0.49	0.33
K_2O	0.72	0.53	0.67
Total	99.90	100.33	100.32
C_4AF	8.8	9.3	7.3
C_3A	12.4	9.0	13.1
C_3S	44.0	57.0	43.0
C_2S	25.5	17.0	28.0
Normal Consistency%	23.5	22.5	23.5
Time of Setting			
Initial (hr:min)	3:00	3:45	3:25
Final (hr:min)	6:30	6:40	6:25
% Retained on No. 200 Sieve	13.6	13.7	11.4
Tensile Strength			
3-day (psi)	257	233	207
7-day (psi)	377	317	293
28-day (psi)	400	420	390
Heat of Hydration (calories/gram)			
3-day	53.1		
7-day	67.7	69.5	74.2
28-day	79.6	77.2	83.7

Reference - History File

Table F2
Barrett Chute GS

Summary of Sand Gradings

Period of Tests		24/01-16/04 1941	16/04-12/06 1941	18/06-28/10 1941	24/07-28/10 1941	21/04-31/07 1941	01/08-13/04 1941-1942
Number of Tests		132	149	245	120	58	150
Source of Sample		unwashed from trucks	unwashed from trucks	washed from trucks	unwashed from conveyor-belt	unwashed from batching hopper	washed from batching hopper
Per Cent Passing							
Sieve No	4	100	100	100	100	100	100
	8	89	86	87	87	87	88
	14	72	67	71	75	70	70
	28	44	41	43	50	45	43
	48	13.4	16.9	15.3	21.1	18.1	15.8
	100	2.3	6.9	4.3	7.6	7.6	4.8
Fineness Modulus		2.80	2.82	2.80	2.57	2.72	2.68

Reference - History File

Table F3
Barrett Chute GS

Grading of Crushed Rock

Screen Size	Main Dam (% passing)		Powerhouse, etc (% passing)	
	Total Sample	Material Passing Sieve No 4	Total Sample	Material Passing Sieve No 4
3"	100.0	--	100.0	--
1-1/2"	72.0	--	88.0	--
3/4"	20.0	--	22.0	--
3/8"	4.0	--	5.0	--
No. 4	0.9	100.0	1.0	100.0
No. 8		78.0		90.0
No. 14		67.0		80.0
No. 28		56.0		70.0
No. 48		45.0		50.0
No. 100		34.0		40.0
Fineness Modulus		2.20		1.70

Reference - History File

Table F4
Barrett Chute GS

Sodium Soundness Tests(*)

No of Cycles	Job Test No 3 Failures	Job Test No 11 Failures	Job Test No 37 Failures	Job Test No 42 Failures
1	0	0	1	0
2	0	0	0	1
3	0	0	0	0
4	0	0	0	0
5	0	0	0	1
6	0	0	0	0
7	0	0	0	0
8	0	0	0	0
9	0	0	0	1
10	0	0	1	0
11	0	0	0	1
12	0	1	0	0
13	0	0	1	0
14	0	0	0	0
15	0	0	0	0
16	0	1	0	1
17	0	0	1	0
18	3	1	1	1
19	1	0	0	0
20	0	0	2	0
Total Failures after 20 Cycles	4	3	7	6
No. of Pieces Tested	10	20	20	20
Weight of Pieces Tested (g)	660.9	1,037.4	1,343.4	1,089.7
Weight of Pieces Left (g)	332.8	884.1	1,025.8	786.6
Weight of Failures (g)	307.6	135.8	263.5	246.2
Total Weight Left (g)	640.4	1,019.9	1,289.3	1,033.8
Loss During Test (g)	20.5	17.5	54.1	55.9
Loss in Small Pieces (g)	22.0	4.6	13.3	6.8

(*) Note: This test was conducted using a modified Sodium Soundness test method employed by Ontario Hydro during the period 1941-1942.

Reference - History File

Table F5
Barrett Chute GS

Concrete Mix Proportions

Mix	A	B	C	D	E	F
Class	Face (Struc)	Face (W.L.)	Face (Struc)	Core (mass)	Core (mass)	Floor Finish
Cement lb	482	525	482	350	350	1,138
Sand lb	1,470	1,470	1,470	1,470	1,530	2,275
Crushed Rock lb	1,830	1,830	915	915	1,840	---
Water lb	310	310	310	310	320	440
Volume of Batch, ft^3	27.17	27.39	21.73	21.95	27.03	26.60
Unit Weight, lb/ft^3	150.6	151.0	146.2	138.7	149.5	144.8
Cement Factor, lb/yd^3	484	525	599	431	350	1,155
w/c Ratio	0.64	0.59	0.64	0.89	0.91	0.39

Reference - History File

Table F6
Barrett Chute GS

Concrete Test Results

Location	Main Dam		Powerhouse
Class	Face	Core (Mass)	Face
Design Strength psi	3000	2000 (assumed)	3000
No. of test cylinders	154	33	138
Avg. Compressive Strength			
7-day psi	3005	1700	2740
28-day psi	4260	2540	4140
Cement Used lb, (bags)/yd^3	482 (5.5)	350 (4.0)	482 (5.5) 569 (6.5)
w/c Ratio	0.64	0.88	0.63
% variation	2.21	3.62	2.31
% design strength	141	127	139
% of Tests below design strength	4.5	7.6	3.6

Reference - History File

Table F7

Table F7
Barrett Chute GS
Results Of Thermocouple Readings

Location	Type of Concrete & Cement Content lb/yd^3	Maximum Temperature	Time to Reach Maximum Temperature (days)
Main Dam*			
Block #7			
Sta 2+59 Elev. 618	Mass (350)	150°F	8
Sta 2+58 Elev. 639	Face (482)	162.5°F	8
Block #8			
Sta 2+85 Elev. 622	Mass (350)	148.5°F	6
Sta 2+85 Elev. 643	Face (482)	164°F	7
Block #9			
Sta 3+11 Elev. 632	Mass (394)	156°F	6
Sta 3+15 Elev. 640	Face (482)	160°F	5
Block #11			
Sta 3+75 Elev. 598	Mass (350)	146°F	12
Sta 3+75 Elev. 636	Face (482)	151°F	9
Block #14			
Sta 4+65 Elev. 597	Mass (350)	143°F	11
Sta 4+64 Elev. 597	Face (482)	154°F	4
Block #16			
Sta 5+24.5 Elev. 583	Mass (350)	132°F	12
Sta 5+24.5 Elev. 583	Face (482)	142°F	5
Sta 5+24 Elev. 592	Mass (350)	139°F	14
Block #19			
Sta 6+52 Elev. 597	Face (525)	135°F	3
Block #20			
Sta 6+79 Elev. 598	Face (525)	158°F	16
Block #21			
Sta 7+13 Elev. 610	Mass (350)	143°F	7
Sta 7+11 Elev. 610	Face (482)	145°F	5
Draft Tube Liners			
Unit #1 Elev. 505.5			
East Side	Face (525)	114°F	3
West Side	Face (525)	110°F	1
Unit #2 Elev. 505.5			
East Side	Face (525)	79°F	2
Diversion Sluice #1			
Center	Face (482)	128°F	11
Faces	Face (482)	70 - 100°F	7 - 8
Diversion Sluice #2			
Center	Face (482)	150°F	

* Note: The measurements in the main dam sections were taken during May - Sept 1941

Reference - Report LO 2817-27
History File

Table F8
Barrett Chute GS
Long-Term Concrete Test

Class		Core (Mass)	Face
Mix Design	1 yd^3		
Cement	lb	350	481
Sand	lb	1,570	1,487
Crushed Rock	lb	1,840	1,770
Water	lb	320	306
w/c ratio		0.92	0.64
Date Cast		20/08/41	29/07/41
Compressive Strength (Average of 3 tests)			
7 day	psi	2030	3260
28 day	psi	2940	4340
90 day	psi	3240	5170
1 year	psi	3320	5260
2 year	psi	4160	5400
3 year	psi	4260	5560
5 year	psi	4140	5700
10 year	psi	4710	6360
15 year	psi	4910	6620

Reference - Report S83-20-H

Table F9
Barrett Chute GS
Results Of Surface Crack Investigation - 1945

Section No.	Depth of Cracks (inches) Average	Maximum	Minimum
9	4.4	15.0	1.0
13	7.6	22.0	1.5
14	4.9	21.0	1.0
15	4.9	24.0	1.0
16	4.5	12.0	1.0
17	7.3	22.5	0.5
18	7.0	37.0	1.0
19	6.5	15.0	3.0
20	8.0	27.0	1.0

Reference - Report LO 40084

APPENDIX G

MOUNTAIN CHUTE GS - MATERIALS SUMMARY

APPENDIX G

Mountain Chute GS - Materials Summary

Constructed 1965-1967 River System - Madawaska

The concrete for this station was produced on site until February 1967. The remaining concrete was supplied by Smith Construction Company from their Burnstown mixing plant. The properties of the materials purchased from the Burnstown mixing plant are contained in Appendix J.

1. Cement

1.1 Source - Canada Cement Company, Belleville Mill.

1.2 Type - Type 10 Normal Portland Cement.

1.3 Physical Properties - The physical properties of the cement are contained in Table G1. These results were obtained from tests on composite samples of the cement used to fill the silo on 5 occassions from May 1965 to September 1966.

1.4 Comments - Every 1000 barrels of cement were tested during the filling of the silos.

1.5 Reference - Central Records File 14-7-256-582
14-7-256-584
Concrete Laboratory C.L. cards

2.0 Fine Aggregate

2.1 Source - Pit at location #4 near the project (natural sand and gravel deposit).

2.2 Physical Properties - Table G2 contains the physical properties of a reference sample of sand. This sample was tested by the Civil Research Department.

2.3 Preparation - The sand was screened and generally had to be blended to meet the specifications.

2.4 Comments - This was a natural deposit containing 20-25% gravel. Pockets of fine silty sand were encountered which required blending.

2.5 References - Research Reports A number of reports were issued on the aggregate survey and testing.
Central Records File 14-7-256-586.

3. Coarse Aggregate

3.1 Source - Quarry at Site 1A (H. Arthur property)

3.2 Physical Properties - Four sizes of crushed rock were produced (6", 3",1 1/2", 3/4"). Table G3 contains the physical properties of reference samples of the 3/4" and 1 1/2" coarse aggregate. These samples were tested by the Civil Research Department. The main components of the rock in this area is biotite and biotite-amphibole gneiss and calcitic marble.

3.3 Preparation - The rock was quarried, crushed and washed to remove the fines.

3.4 Comments - In the winter of 1966 the rock was dirty and could not be washed due to the low temperatures. When this material was used, additional cement had to be added to the mix.

The large size aggregates were difficult to produce because the rock tended to break during production and transportation. The excavated rock was generally not used because of its weathered and altered state. Near the end of concrete production at Mountain Chute GS some 3" and 3/4" coarse aggregate was purchased from Smith Construction Company.

3.5 Reference - Research Reports — A number of reports were issued on the aggregate survey and testing.

Central Records File — 14-7-256-586.

4. Admixtures

4.1 Type - Daravair (air entraining)
Daramix (water reducing)

4.2 Comments - None

4.3 References - Central Records File 14-7-255-556 Concrete inspectors
14-7-255-563 daily reports.
to 14-7-255-573

5. Fly Ash

5.1 Source - Detroit Edison Company, Trenton Channel plant.
- Ontario Hydro, R.L. Hearn GS.

5.2 Physical Properties - A summary of the results of tests on fly ash is given in Table G4. These tests were conducted by Ontario Hydro unless otherwise stated.

5.3 Comments - Fly ash was used as a 20 to 30% replacement of cement in some mixes. The carbon content of the R.L. Hearn GS fly ash was very high (10.16%). This material was used in June 1966 and caused considerable problems with the air content and consistency of the mix. The Detroit Edison fly ash was used for the majority of the project. On some occassions the mixing plant would run out of fly ash mid way through a pour.

5.4 Reference - Report S67-8-H Summary of the supply of fly ash.

6 Water - Information not available.

7. Concrete

7.1 Classes - The two main classes of concrete were mass and structural (face) with about 11 different mixes being used.

7.2 Mixes - Table G5 contains the proportions for the various mixes. The proportions changed as the performance of the concrete was established. The amount of cement was reduced in most mixes once the problems with the mixing plant and the placing operations had been eliminated. The cement content had to be increased when dirty aggregate was used in the winter. Near the end of concrete production at Mountain Chute GS the proportions of the coarse aggregates were altered to take advantage of the quantities of crushed rock available.

7.3 Strength Results - Table G6 contains typical results of tests on the concrete cylinders. These results only represent a portion of the concrete tests performed on site.

7.4 Defects - Considerable problems were encountered with the consolidation of the concrete during the first few months of construction. Some of the factors that were thought to have contributed to this were the use of maximum 6" aggregate, inexperienced placing crews and problems with the vibrators. A small bulldozer was also used in the form to spread the concrete. The amount of honeycombing in the concrete, observed during the first few months, was higher than considered normal.

Soniscope tests were performed on Sections S6 and 16 in November 1965. The report (65-494) issued on this investigation concluded that there were some areas in both of these sections that contained concrete of questionable quality. Restricted access for the Soniscope equipment limited its effectiveness for this investigation. Another Soniscope survey was conducted in January 1966 and the results presented in Report 66-94-H. This report concluded that the areas of questionable concrete appeared to be horizontal in nature and at or near construction joints.

After drill cores had been obtained from some of the blocks, it was decided that a water testing and repair program would be conducted on sections where the consolidation of the concrete was questionable. This included Sections 6, 10, 12 and 16 and proposals for Sections 2, 4 and 14. The blocks were drilled, cores were obtained and tested and the drill holes water and Soniscope tested. It was proposed that a 4' wall be constructed upstream from blocks where the concrete was questionable.

7.5 Instrumentation - Thermocouples were placed in a number of sections and temperature readings of the concrete taken up to a period of 1 month after placing. The maximum temperature was usually reached after 5 days and was recorded to be 104°F (Section 4-HT-10).

7.6 Comments - None

7.7 References - Research Reports 65-494 Soniscope tests on 66-95-H Sections 6 and 16.

Central Records File 14-7-255-556 Concrete inspector daily reports. to 14-7-255-573

14-7-255-552 Concrete test results. to 14-7-255-559

14-7-256-582 Drilling and water testing of various blocks of the main dam. 14-7-256-600

8. Miscellaneous

8.1 Reference - Central Records File 14-7-255-575 General file. to 14-7-255-586 14-7-257-626

9. Post-Construction Investigation

9.1 Investigations

9.1.1 Long-Term Concrete Tests - The results to date of the long-term tests on concrete cylinders cast during construction are given in Table G7. The test specimens reached their maximum compressive strength after about one year.

9.2 Reference-Report S83-20-H Long-term concrete tests.

Table G1

Mountain Chute GS
Physical Properties of Cement

% Retained on No. 200 Sieve	6.2
Blaine cm^2/g	3180
Autoclave Expansion %	0.472
Normal Consistency	23.0
Set Initial (hr:min)	2:05
Final (hr:min)	3:30
Compressive Strength (psi)	
3-day	2880
7-day	3570
28-day	4235

Reference - Concrete Laboratory C.L. Cards

Table G2

Mountain Chute GS
Physical Properties of Reference Sample of Sand

Sieve Size	% Passing
3/4"	100
No. 4	95.5
(Assume 100%) No. 4	100
No. 8	88.6
No. 16	71.9
No. 30	48.2
No. 50	23.2
No. 100	8.8
No. 200	4.54
Fineness Modulus (F.M.)	2.59
Specific Gravity	2.71
Absorption %	1.26
Soundness - Weighted	1.73
Loss After 5 cycles %	

Reference - Central Records File 14-7-256-586

Table G3

Mountain Chute GS
Physical Properties of Reference Samples of Coarse Aggregate

Screen Size	3/4" - No. 4	1 1/2" - 3/4"
	% Passing	% Passing
3"	-	100
1 1/2"	100	99.7
3/4"	99.9	50.4
3/8"	28.7	14.1
No. 4	7.4	10.3
Specific Gravity	2.84	2.82
Absorption %	0.24	0.18
Soundness - Weighted Loss After 5 cycles %	1.6	0.8

Reference - Central Records File 14-7-256-586

Table G4

Mountain Chute GS
Summary of Tests on Fly Ash

Source		Detroit Edison	R.L. Hearn GS
Specific Gravity	avg.	2.19	2.38
	range	2.15 - 2.32	2.34 - 2.43
Moisture %	avg.	0.16	0.10
	range	0.03 - 0.48	0.0 - 0.50
Loss on Ignition %	avg.	3.82	10.16
	range	3.24 - 4.52	8.00 - 13.34
Blaine (cm^2/g)	avg.	3310	4190
	range	3070 - 3580	3780 - 4660
Mean Particle Diameter (Microns)	avg.	8.30	6.06
	range	7.37 - 9.09	5.41 - 6.61
Number of tests carried out at plant for loss on ignition		403	9
Loss on Ignition %	avg.	4.06	10.16
	range	2.60 - 7.08	8.00 - 13.34
Number of tests by Ontario Hydro at Detroit Edison Plant for Loss on Ignition		15	
Loss on Ignition %	avg.	3.82	-
	range	3.24 - 4.52	-

Reference - Report S67-8-H

Table G5

Mountain Chute GS
Mix Proportions
(1 cu yd)

Type of Concrete	Cement lbs	Fly Ash lbs	Water lbs	W/C Ratio	Sand lbs	Cobble 6" lbs	Coarse 3" lbs	Medium 1 1/2" lbs	Fine 3/4"lbs
Mass Gravity									
Mass Core	141	60	161	0.80	1000	850	760	1220	-
Mass Ext	200	85	182	0.64	1159	785	695	1050	-
Mass W/L	315	79	197	0.50	1115	750	875	550	-
Mass Deck	394	-	236	0.60	1050	-	480	955	905
Apron	459	-	253	0.55	1085	-	450	900	845
Structural (Face)									
Str. Gen.	333	83	249	0.60	1225	-	-	1230	920
Sill	350	88	219	0.50	1145	-	-	-	500
Mod. Str	245	105	210	0.60	1180	-	700	1250	420
Mod. Core	184	79	205	0.78	1130	-	645	1030	840
Str W/L	368	92	230	0.50	1230	-	-	1235	925
Str Deck	438	-	263	0.60	1235	-	-	1225	805

Reference - Central Records File 14-7-256-579

Table G6

Mountain Chute GS
Typical Concrete Test Results

Class of Concrete	Cement lb/yd^3	Fly Ash %	W/C Ratio	No. of Tests	28-Day Compressive Strength psi Design(days)	High	Low	Avg.
Mass Gravity								
Mass Core	141	30	0.80	80	1750(90)	2950	1380	2189
Mass Ext	200	30	0.64	100	3000(90)	4280	2250	3475
Mass W/L	315	20	0.50	47	3000(90)	5600	3040	4739
Mass Deck	394	-	0.60	31	3000(90)	4880	3070	4026
Apron	459	-	0.55	2	4000(90)	4990	4870	4930
Structural (Face)								
Str Gen	333	20	0.60	21	3000(28)	5140	3500	4270
Mod Str	245	30	0.60	47	2500(28)	4420	2700	3512
Mod Core	184	30	0.78	5	2500(90)	2490	2210	2336
Str W/L	368	20	0.50	16	3000(28)	5420	4300	4911
Str Deck	438	-	0.60	7	3000(28)	4480	3890	4081

Reference - Central Records File 14-7-255-553

Table G7

Mountain Chute GS
Long Term Concrete Tests

Class of Concrete	Mass Core	Mass Exterior	Mass Exterior	Str Gen.
Location	Gravity Block N2N	Gravity Block N1S	Gravity Block S8V	Sluice Apron SA5
Pour No.	MD 373	MD 380	MD 858	MD 875
Cement, lb (bag)/yd^3	201 (2.3)	306 (3.5)	284 (3.25)	416 (4.75)
W/C Ratio	0.78	0.59	0.63	0.56
Unit Weight, lb/ft^3	147.7	146.4	147.7	146.4
Air %	8.1	7.3	6.2	6.4
Date Cast	22/11/65	26/11/65	31/10/66	22/11/66
Compressive Strength, (psi)				
7 day	-	-	1910	2570
28 day	-	-	3170	3200
90 day	2930	4610	4370	4360
1 year	3760	5680	5620	4600
2 year	3670	5390	5950	-
3 year	3760	5980	5260	4470
5 year	3400	5280	5600	4630
10 year	3730	5750	5740	4520
15 year	3860	6090	6000	4450

Reference - Report S83-20-H

APPENDIX H

KAMANISKEG LAKE DAM - MATERIALS SUMMARY

APPENDIX H

Kamaniskeg Lake Dam - Materials Summary

Constructed 1956 - 1957 River System - Madawaska

There is very little information on this project stored with the Civil Research Department. Most of the available files and reports are located in Central Records.

This is a small storage dam, initially estimated to require about 2450 yd^3 of concrete.

1. Cement

1.1 Source - St Marys Cement Company, St Marys Ontario.

1.2 Type - Type 10 Normal Portland Cement (brand name - Pyramid).

1.3 Physical Properties - Table H1 contains the physical properties of the cement obtained from tests on nine samples. This represents about 394 tons of cement.

1.4 Comments - The cement samples tested met the CSA specifications for Type 10, Normal Portland Cement.

1.5 Reference - Concrete Laboratory C.L. Cards

2. Fine Aggregate

2.1 Source - Paugh Lake Road pit (natural sand deposit).

2.2 Physical Properties - Table H2 contains the average gradings of sand sampled from the stockpiles at the aggregate pit and at the dam site.

2.3 Preparation - The sand was screened at the pit and transported to the site.

2.4 Comments - This is the same source of fine aggregate as used for the construction of Bark Lake Dam. The fineness modulus (F.M.) obtained from tests on samples from the stockpile located at the dam was 2.62. During the construction of Bark Lake Dam, it was reported that 40% of the pit run material was unacceptable and had to be wasted. The specific gravity of this sand determined in 1941 - 1942 was 2.70 and the loose density was 81.1 lb/ft^3.

2.5 References - Central Records File 14-7-262-872
14-7-262-873 - Gradings of sand

3. Coarse Aggregate

3.1 Source - Stockpile at Bark Lake Dam.
- Screened gravel from the Paugh Lake Road pit.

3.2 Physical Properties - Most of the coarse aggregate was obtained from the crushed rock stored at Bark Lake dam. This material was mainly in the 3/4" to 1 1/2" size range. Table H3 contains the average gradings of samples from the crushed rock stockpile at the dam.

Results of soundness tests conducted on the coarse aggregate screened from the Paugh Lake pit are given in Table H4. These tests were conducted during the construction of Bark Lake Dam (1941) and during the construction of this project (1956).

3.3 Preparation - The crushed rock was transported from Bark Lake Dam and stockpiled at the project site. The gravel was screened from the sand at Paugh Lake Road pit and transported to the site.

3.4 Comments - Initially it was felt that the stockpile of crushed rock remaining after the construction of Bark Lake Dam would be sufficient to supply this project. It turned out after construction had begun that an additional source of coarse aggregate would be required. The stone screened from the fine aggregate at Paugh Lake Road pit was used to supplement the crushed rock. This stone had originally been rejected for use on the Bark Lake project. The stone had failed soundness tests in 1941, but passed similar tests in 1956 (test results in Table H4). The gravel from the Paugh Lake Road pit was to be mixed with the Bark Lake crushed rock, but this was not always done, especially when the gravel was first used.

The specific gravity of the crushed rock determined in 1941-1942 was 2.73 and the loose density was 85.4 lb/ft^3.

3.5 References - Central Records File 14-7-262-872
14-7-262-873 Gradings of crushed rock.

4. Admixtures

4.1 Not used on this project except as indicated in Section 4.2.

4.2 Comments - Admixtures were used on this project only for trial testing. Darex was added to the concrete in Pier #5 of the north channel dam and in the slabs of Pier #6 of the south channel dam (1/2 oz per 87.5 lb of cement). Pozzolith was used in the slabs of Pier #6 and Pier #8 of the south channel dam (4 oz per 87.5 lb of cement).

4.2 Reference - Central Records File 14-7-262-873
14-7-262-874

5. Fly Ash - Not used on this project.

6. Water - Information not available.

7. Concrete

7.1 Classes - One class of concrete was used, containing 569 lb/yd^3 of cement with a specified compressive strength of 3000 psi at 28 days.

7.2 Mixes - The mix proportions recommended for this job are given in Table H5. These values were determined assuming the crushed rock from Bark Lake Dam would be used as the coarse aggregate.

7.3 Strength Results - Table H6 contains the results of the concrete cylinder tests conducted during construction. The average compressive strength was 3960 psi at 28 days, the unit weight was 148.9 lb/ft^3 and the water/cement ratio was 0.56. Of the cylinders tested, 5.3% failed to meet the design compressive strength.

7.4 Defects - Low compressive strengths were obtained from 7- and 28-day tests on cylinders representing the concrete placed in the centre wing wall and Pier S-1 of the south channel dam. A concrete test hammer was used to determine the strength of the concrete in this area after 34 days. The results from this investigation indicated that the concrete had an average strength of 4910 psi. The only possible reason suggested for the low test results of the concrete cylinders was that there may have been an excessive amount of gravel from the Paugh Lake Road pit in the mix.

7.5 Instrumentation - Information not available.

7.6 Comments - None

7.7 References - Central Records File 14-7-262-873
14-7-262-874 - Concrete test results.

8. Miscellaneous

8.1 Reference - Central Records File 14-7-262-873 - General file.

9. Post-Construction Investigation - Information not available.

Table H1
Kamaniskeg Lake Dam

Physical Properties of Cement

% Retained on No. 200 Sieve	10.0
Normal Consistency %	23.2
Time of Set Initial (hr:min)	2:25
Final (hr:min)	4:00
Autoclave Expansion %	0.396
Compressive Strength psi	
3-day	1905
7-day	2735
28-day	3935

Reference - Concrete Laboratory C.L. Cards

Table H2
Kamaniskeg Lake Dam

Summary of Sand Gradings

Source of Sample	Stockpile at Pit	Stockpile at Dam
Number of Tests	32	39
Over Size %	5.2	8.2
% Passing Sieve		
No 8	90.5	88.0
No 14	73.5	72.1
No 28	50.8	51.4
No 48	20.8	19.8
No 100	5.4	5.1
Fineness Modulus F.M.	2.60	2.62

Reference - Central Records File 14-7-262-873.

Table H3
Kamaniskeg Lake Dam

Summary of Stone Gradings

Source of Sample	Stockpile at Dam
% Passing Screen Size	% Passing
1-1/2"	80.4
3/4"	30.3
3/8"	10.2
No 4	7.3
Number of Tests	29

Reference - Central Records File 14-7-262-873

Table H4
Kamaniskeg Lake Dam

Soundness Tests

Year	Failure in 5 cycles	Failures in 20 Cycles	Test Method
1941	3	8	20 Stone Soundness
1941	4	8	" " "
1941	5	10	" " "
1956	1	3	" " "
1956	4.4% Loss	--	ASTM

Reference - Central Records File 14-7-262-872

Table H5
Kamaniskeg Lake Dam

Recommended Mix Proportions (1 yd^3)

Material	Weight
Cement, lb	569 (6-1/2 bags)
Sand (dry weight), lb	1340
Crushed stone, lb	1850
Water, lbs	330
w/c ratio	0.58

Reference - Central Records File 14-7-262-872

Table H6
Kamaniskeg Lake Dam

Summary of Concrete Tests

Number of tests	19
Compressive Strength	
7-day, psi	2255
28-day, psi*	3960
% below design strength	5.3%
w/c ratio	0.56
Unit Weight, lb/ft^3	148.9

* Each test consists of the average of two cylinders.

Reference - Central Records File 14-7-262-874

APPENDIX I

BARK LAKE DAM - MATERIALS SUMMARY

APPENDIX I

Bark Lake Dam - Materials Summary

Constructed 1941 - 1942 River System - Madawaska

Most of the information dealing with this project is located in a report produced by the Civil Research Department at the time of construction. Other than this report, there is very little information on the original construction of this dam.

This dam was constructed by the Dominion Construction Co. Ltd.

1. Cement

1.1 Source - Canada Cement Co. Ltd., Hull Mill.

1.2 Type - Modified Type 10 Normal Portland Cement (see Section 1.4).

1.3 Physical Properties - Table I1 contains the average of the results obtained from the physical tests and chemical analysis performed on nine composite samples of cement delivered to the site. These samples cover a period from 22/08/41 - 25/02/42.

1.4 Comments - The normal portland cement was modified to try and meet the CSA requirements for Type 20 cement (moderate low heat). The cement satisfied the specifications for Type 10, but in some areas did not always meet the specifications for Type 20 cement. This was the same type of cement as used on the Barrett Chute project.

1.5 Reference - Central Records File 14-7-264-1091 Report on cement.
History File
Concrete Laboratory - C.L. cards

2. Fine Aggregate

2.1 Source - Paugh Lake Road Sand pit.
- Natural sand deposit.

2.2 Physical Properties - Table I2 contains the grading of the sand sampled during the preliminary investigation, screening and concreting operations. The specific gravity of the sand was 2.70 and loose density was 81.1 lb/ft^3.

2.3 Preparation - The sand was screened at the pit and then transported to the site.

2.4 Comments - About 40% of the pit run material was unacceptable and wasted back into the pit. The aggregate had a fineness modulus (F.M.) of 2.66. All the sand used was from the Paugh Lake Road pit, except 70 yd^3 from Joliett Quebec.

2.5 Reference - History File

3. Coarse Aggregate

3.1 Source - Quarry located near the mixing plant.

3.2 Physical Properties - Table I3 contains the grading of the crushed rock. The samples were taken from the end of the conveyer belt after screening. The specific gravity of the crushed rock was 2.73 and the loose density was 85.4 lb/ft^3.

3.3 Preparations - The rock was crushed and screened.

3.4 Comments - Only one size of coarse aggregate was used on this project. Most of this material was in the 3/4" to 1-1/2" size range. The first quarry was eventually condemned and a second quarry had to be opened.

3.5 Reference - History File

4. Admixtures - Not used on this job.

5. Fly Ash - Not used on this job.

6. Water - Information not available.

7. Concrete

7.1 Classes - One class of concrete was used containing 569 lbs/yd^3 (6-1/2 bags) of cement with a design strength of 3000 psi.

7.2 Mixes - The basic mix proportions are given in Table I4.

7.3 Strength Results - The results of the concrete cylinder tests conducted during construction are given in Table I5. The concrete had an average compressive strength of 3630 psi and a unit weight of 149.8 lb/ft^3. Of the tests performed, 6.4% fell below the design strength.

7.4 Defects - Sketches with the location of cracks noticed during construction are stored in the History File. On three occasions the forms lifted or bulged during concrete placing.

7.5 Instrumentation - A pipe was placed in Section 2 of the bulkhead wall and was used to take temperature readings of the concrete. The maximum

temperature reached was 139°F after six days. A list of the readings obtained in this Section are located in the History File.

7.6 Comments - None

7.7 Reference - History File

8. Miscellaneous

8.1 Reference - Central Records File 14-7-265-1091 General file.

9. Post-Construction Investigations

9.1 Investigations

9.1.1 Condition of Concrete 1951 - An inspection of the concrete was conducted in 1951 and reported in 1952. Report 52-368 concluded that the concrete was in generally good condition. Areas of slight seepage and cracks visible after construction (1942) had healed. The only cracking occurred in sections adjacent to the sluiceways and these cracks did not appear to be deep.

9.2 Reference - Report 52-368 Concrete inspection 1951.

Table I1
Bark Lake Dam

Chemical Composition and Physical Properties of Cement

Physical Properties		Chemical Composition	
% Retained on No. 200 Sieve	12.2	Composition	(% by weight)
Normal Consistency %	22.8	SiO_2	21.46
Time of Initial Set (hr:min)	3:20	CaO	64.28
Final Set (hr:min)	6:40	Fe_2O_3	3.10
Tensile (psi)		Al_2O_3	5.42
Age 3 days	248	MgO	2.82
7 days	323	Na_2O	0.57
28 days	431	K_2O	0.54
		SO_3	1.62
		Total	99.81
		Compound Composition	
		3 $CaOSiO_2$	53.34
		2 $CaOSiO_2$	21.32
		3 $CaOAl_2O_3$	8.94
		4 $CaOAl_2O_3Fe_2O_3$	9.38

Reference - History File
Concrete Laboratory C.L. Cards

Table I2
Bark Lake Dam
Summary of Sand Grading

Source of Analysis		Preliminary Investigations	Screening Operations	Concreting Operations
			% Passing	
Sieve Size	No. 4	100	100	100
	No. 8	78.5	88.5	88.0
	No. 14	55.6	71.0	70.6
	No. 28	31.6	47.2	48.5
	No. 48	11.1	21.0	21.6
	No.100	2.75	5.1	4.4
Fineness Modulus		3.22	2.68	2.66

Reference - History File

Table I3
Bark Lake Dam

Grading of Crushed Rock

Screen Size	Percent Passing
3"	100
1-1/2"	70.0
3/4"	16.2
3/8"	4.0
No. 4	2.0

Reference - History File

Table I4
Bark Lake Dam

Concrete Mix Proportions for 1 yd^3

Material	Weight (lbs)
Cement	569 (6-1/2 bags)
Water	330
Fine Aggregate	1340
Coarse Aggregate	1850
w/c Ratio	0.58

Reference - History File

Table I5
Bark Lake Dam

Summary of Concrete Test

No of Tests	78
Compressive Strength psi	
7-day	2385
28-day*	3630
Design Strength psi	3000
% Below Design Strength	6.4
w/c Ratio	0.57
Unit Weight lb/ft^3	149.8

*Each test consists of the average obtained from 2 cylinders

Reference - History File

APPENDIX J

BARRETT CHUTE GS EXTENSION, STEWARTVILLE GS EXTENSION
AND CALABOGIE GS REMEDIAL WORK - MATERIALS SUMMARY

APPENDIX J

Barrett Chute GS Extension, Stewartville GS
Extension and Calabogie GS Remedial Work - Materials Summary

Constructed 1966 - 1969 River System - Madawaska

In the late 1960's, extensions were added to Barrett Chute GS and Stewartville GS and remedial work performed on Calabogie GS. Smith Construction supplied the concrete used on all three projects. This concrete was also used for the completion of Mountain Chute GS after February 1967.

In Central Records the information on the extension work is located under all of the four stations (Barrett Chute GS, Stewartville GS, Mountain Chute GS and Calabogie GS).

1. Cement

1.1 Source - Canada Cement Company, Hull, Quebec plant.

1.2 Type - Special Low Heat Portland cement.

1.3 Physical Properties - Table J1 contains the physical and chemical properties of this cement. These values represent the results of 30 tests conducted on approximately 78,500 barrels of cement produced by Canada Cement Company at their Hull, Quebec plant between August 4 and September 5, 1966.

1.4 Comments - Special Low Heat Portland Cement was used as an alternative to a combination of Type 10 Normal Portland cement and fly ash. When this cement was initially produced, there were difficulties in meeting the strict specifications. This was the first time Ontario Hydro had used this type of cement and they had adopted the specifications issued by Hydro Quebec. The acceptance criteria was eventually relaxed and special actions (such as using additional cement) were taken as needed.

At the beginning of the concreting operation at Barrett Chute GS, some Type 10 cement was used.

1.5 References - Report S66-53-H Low heat cement.
SC66-67-H Low heat cement.
Central Records File 14-7-252-408
Laboratory File 451.14.1 Special Low Heat Cement.
10.2.1 Cement tests.
10.4.1 Cement tests.
Concrete Laboratory C.L. Cards - Records of tests on cement.

2. Fine Aggregate

2.1 Source - McLaren's pit
- Natural sand and gravel deposit.

2.2 Physical Properties - In Table J2 the physical properties of a reference sample of the sand used on these projects are given. This sample was obtained from the stockpile at the ready-mix plant and tested by the Civil Research Department.

2.3 Preparation - The sand was screened at the pit and transported to the stockpile at Smith Brothers Ready Mix plant at Burnstown.

2.4 Comments - This was the same aggregate source as used to supply the original construction of Stewartville GS. The fineness modulus (F.M.) of the sand at the mixing plant was about 2.85. The petrographic number for sand from this pit was 105.0 for the No. 16 material and 102.0 for the No. 30 material.

2.5 References - Report S73-53-K Petrographic numbers.
Central Records File 14-7-265-1082
14-7-265-1085 Concrete inspectors reports Barrett Chute GS.
14-7-252-413 to 14-7-252-419 Concrete inspectors reports Stewartville GS.
14-7-267-1163 Concrete inspectors reports Calabogie GS.
Laboratory File 10.2.1

3. Coarse Aggregate

3.1 Source - Jamieson's pit
- McLaren's pit
Natural sand and gravel deposits.

3.2 Physical Properties - Three sizes of coarse aggregate were used (3/4", 1 1/2" and 3"). Table J3 contains the physical properties of a reference sample of the coarse aggregate. The sample was obtained from the stockpiles at the mixing plant and does not include any 3" stone. This material came from McLaren's pit and was tested by the Civil Research Department.

The parent rock in this area is mainly composed of aplite, aplitic and brotite gneisses with some dolomitic and calcitic marbles. A detailed petrographical analysis on samples from this pit is found in Report S66 -32-H.

3.3 Preparation - The pit run material was screened and any oversized material crushed. The stone was then stockpiled at the Smith Construction Ready Mix plant at Burnstown.

3.4 Comments - The coarse aggregate was obtained primarily from the Jamieson pit. Some of the material screened from the fine aggregate pit (McLaren's pit) was also used.

3.5 References - Report S66-32-H Petrographic analysis

Central Records File - 14-7-265-1082
14-7-265-1085 Concrete inspectors reports Barrett Chute GS.
14-7-252-413 Concrete inspectors reports
to 14-7-252-419 Stewartville GS.
14-7-267-1163 Concrete inspectors reports Calabogie GS.

Laboratory File 10.2.1
10.3.1

4. Admixtures

4.1 Type Pozzolith 4H - water-reducing admixture.
MBVR (Master Builders Vinsol Resin) - air-entraining admixture.

4.2 Comments - From 1 to 5 oz of MBVR was used per yd^3 of concrete. One quarter of a pound of Pozzolith 4H, was used per bag of cement (87.5 lb cement = 1 bag). Some Liguim S.F. was also used on a few occassions in place of Pozzolith 4H.

4.3 Reference - Central Records File 14-7-265-1085 Concrete inspectors reports Barrett Chute GS.
14-7-252-413 Concrete inspectors reports
to 14-7-252-419 Stewartville GS.
14-7-267-1163 Concrete inspectors reports Calabogie GS.

5. Fly Ash - Not used on this project.

6. Water - Information not available.

7. Concrete

7.1 Classes - There were 4 main classes of concrete.

Class A (mass)	specified strength 2500 psi, 3" max aggregate
Class B (face)	specified strength 3000 psi, 1 1/2" max aggregate
Class C (miscellaneous)	specified strength 3000 psi, 3/4" max aggregate
Class D (waterline)	information not available.

7.2 Mixes - The mix proportion for the main classes of concrete are given in Table J4. There were also some special mixes used for floor finishing and grout.

7.3 Strength Results - Tables J5 and J6 contain the concrete test results for Calabogie GS and Barrett Chute GS, respectively. Concrete cylinders were tested at 7, 28, 49 and 90 days. Of the Barrett Chute GS test results, 7.0% of the Class A (mass) concrete and 7.7% of the Class B (face) concrete failed to meet the design compressive strength after 28 days.

7.4 Defects - No information available.

7.5 Instrumentation - No information available.

7.6 Comments - The concrete was produced by Smith Construction at their Ready Mix plant at Burnstown.

7.7 References - Central Records File

14-7-267-1163	Daily concrete inspection reports for Calabogie GS.
14-7-265-1085	Daily concrete inspection reports for Barrett Chute GS.
14-7-252-413 to 14-7-252-419	Daily concrete inspection reports for Stewartville GS.

	14-7-255-552	Concrete test results
to	14-7-255-555	for a variety of stations.
	14-7-257-627	
	14-7-256-586	
	14-7-265-1087	Concrete test results for Barrett Chute GS.

8. Miscellaneous

8.1	Reference - Central Records File	14-7-257-626	Monthly progress reports.
		14-7-255-575	Weekly progress reports.
		14-7-252-408	General files.
		14-7-252-412	
		14-7-256-583	
		to 14-7-256-586	
		14-7-265-1082	
	Laboratory File 10.2.1		

9. Post-Construction Investigations

9.1 Investigation

9.1.1 Long-Term Concrete Tests - Concrete cylinders were cast at Stewartville GS in October 1968 and were to be tested at various intervals up to 100 years. To date they have been tested to 16 2/3 years and have exibited a general increase in compressive strength. The results of the tests performed and the mix proportions are given in Table J7.

9.2 References - Report S83-20-H Long-term concrete tests.

Table J1

Barrett Chute GS, Stewartville GS, and Calabogie GS
Chemical Composition and Physical Properties of Cement

Chemical

Composition	% By Weight
SO_3	2.1
SiO_2	23.9
Fe_2O_3	3.4
Al_2O_3	4.2
CaO	62.5
MgO	2.6
Na_2O	0.21
K_2O	0.52
Loss on Ignition	0.46
Total	99.89
Compound Composition	
$3CaO\ SiO_2$	34
$2CaO\ SiO_2$	43
$3CaO\ Al_2O_3$	5
$4CaOAl_2O_3Fe_2O_3$	10

Physical

% Retained on No. 200 Sieve	1.2
Time of Set	
Initial (hr:min)	4:10
Final (hr:min)	6:15
Blaine cm^2/g	3160
Autoclave Expansion %	0.072
Compressive Strength	
3-day psi	1880
7-day psi	2640
28-day psi	4715
Heat of Hydration	
Calories/gram at 7 days	64

Reference - Concrete Laboratory File 451.14.1

Table J2

Barrett Chute GS, Stewartville GS, and Calabogie GS
Physical Properties of Sand

Sieve Size	% Passing
No. 4	100
No. 8	89.7
No. 16	70.7
No. 30	40.4
No. 50	11.6
No. 100	2.8
No. 200	1.77
% Retained on No. 4 Sieve	3.8
Fineness Modulus (F.M.)	2.85
Apparent Specific Gravity	2.73
Absorption %	1.03
Soundness - Weighted Loss After 5 cycles %	1.72

Reference - Concrete Laboratory File 10.2.1

Table J3

Barrett Chute GS, Stewartville GS, and Calabogie GS
Physical Properties of Coarse Aggregate*

Screen Size	% Passing
1 1/2"	100
3/4"	58.4
3/8"	18.0
No. 4	3.3
Apparent Specific Gravity	2.74
Absorption %	0.48
Soundness - Weighted loss after 5 cycles %	1.2

* 3" material not included in this sample.

Reference - Concrete Laboratory File 10.2.1

Table J4

Barrett Chute GS, Stewartville GS, and Calabogie GS
Concrete Mix Proportions (1 yd^3)

Class of Concrete	A	B	C	D	P-1
Cement, lb	350	400	435	450	550
Total Water, lb	212	225	252	220	270
W/C Ratio	0.61	0.56	0.58	0.49	0.49
Sand, lb	1198	1380	1540	1300	1895
3/4" Stone, lb	370	900	1800	835	1315
1 1/2" Stone, lb	1000	1100	-	1285	-
3" Stone, lb	1000	-	-	-	-

Reference - Central Records File 14-7-267-1163
14-7-265-1085
14-7-252-413 to 14-7-252-419

Table J5
Barrett Chute GS, Stewartville GS, and Calabogie GS
Concrete Test Results

	Calabogie GS			
Concrete Class	A	B	D	P1
No. of Tests	2	13	21	10
W/C Ratio	0.58	0.57	0.54	0.51
Slump	2"	2 1/2"	2 3/4"	2 1/2"
Cement, lb(bag)/yd^3	350 (4.0)	400 (4.6)	455 (5.2)	550 (6.3)
Air %	4.8	5.8	5.7	6.1
Unit wt, lb/ft^3	148.9	147.8	148.9	145.7
Compressive Strength, psi				
7 day	2565	2060	2460	2990
28 day	4030	3335	3880	4445
49 day	4620	3955	4460	4825
90 day *	6035 (1)	4655 (3)	5450 (6)	5895 (4)

* Number in brackets indicates number of tests.
Reference - Central Records File 14-7-267-1163

Table J6

Barrett Chute GS, Stewartville GS, and Calabogie GS
Concrete Test Results

Barrett Chute GS

Concrete Class	A	B	C	D	F	P1
No. of Tests	116	65	18	32	8	12
W/C Ratio	0.57	0.57	0.57	0.50	0.56	0.53
Slump	2 1/2"	2 3/4"	3 1/4"	2 1/2"	2 3/4"	3 1/2"
Cement, lb (bag)/yd^3	362 (4.1)	404 (4.6)	438 (5.0)	455 (5.2)	438 (5.0)	551 (6.3)
Air %	5.4	5.8	5.0	5.5	4.3	4.9
Unit wt. lb/ft^3	148.8	148.0	148.0	149.9	149.6	146.5
Compressive Strength, psi						
7 day	2210	2205	2295	2660	3210	2615
28 day	3535	3595	3920	4160	4225	4460
49 day	4305	4300	4635	4895	4560	5055
90 day *	5350 (33)	5315 (15)	5530 (2)	6015 (10)	4850 (1)	-

* Number in brackets indicates number of tests.

Reference - Central Records File 14-7-265-1087.

Table J7

Barrett Chute GS, Stewartville GS, and Calabogie GS
Long-Term Concrete Tests

Mix Design for 1 yd^3

Cement, lb	400 (low heat)
Water, lb	185
w/c Ratio	0.46
Sand, lb	1380
3/4" Stone, lb	900
1 1/2" Stone, lb	1100
Air %	6.1
Admixtures	
4H Pozzolith, lb	2.34
MBVR, oz	3.5
Date Cast	08/10/68

Compressive Strength*, psi

7 day	2240
28 day	3500
49 day	4740
90 day	5500
1 year	6310
2 years	6430
3 years	6470
5 years	6580
10 years	6340
16 2/3 years	6510

* Each value of compressive strength is the average of two test results.

These cylinders were cast at Stewartville GS, but can be assumed to represent the concrete placed at Barrett Chute GS and Calabogie GS during the same period.

Reference - Report S83-20-H

DISTRIBUTION

Mr. J.V. Doyle	Thermal & Hydraulic Generation, A5H4
Mr. O. Bernaus	Thermal & Hydraulic Generation, A5H6
Mr. I. Azis(3)	Thermal & Hydraulic Generation, A5H8
Mr. P. Kalnins	Design & Development - Gen, H18F11
Mr. L.A. Leeyus	Design & Development - Gen, H17A27
Dr. T.W. Klym	Civil Research Department
Mr. C.B. Cragg	Civil Research Department
Mr. G.S. Kellay	Civil Research Department
Dr. R.D. Hooton	Civil Research Department
Mr. P.K. Mukherjee	Civil Research Department
Mr. E. McColm	Civil Research Department

Public Reference Centre
Editorial Section (2)
Extra Copies (2)
Office Copies (3)

- last page -